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Building Resilience to Climate Change in Pacific Communities

Informing climate-resilient development: the application of cost–benefit analysis (CBA) in the Pacific Adaptation to Climate Change (PACC) programme

Experiences and lessons learned in the application of CBA to PACC demonstration projects

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Buncle, Aaron.

Informing-climate resilient development: the application of cost-benefit analysis (CBA) in the Pacific Adaptation to Climate Change (PACC) Programme : experiences and lessonslearned in the application of CBA to PACC demonstration projects / Aaron Buncle – Apia, Samoa : SPREP, 2013.

p. cm. (PACC Technical Report No.2)

ISBN: 978-982-04-0499-1 (print)
978-982-04-0500-4 (ecopy)

1. Sustainable development – Oceania. 2. Climatic changes – Oceania
3. Climate changes – Economic aspects – Oceania. I. Buncle, Aaron.
II. Pacific Regional Environment Programme (SPREP) IV. Title.

338.996

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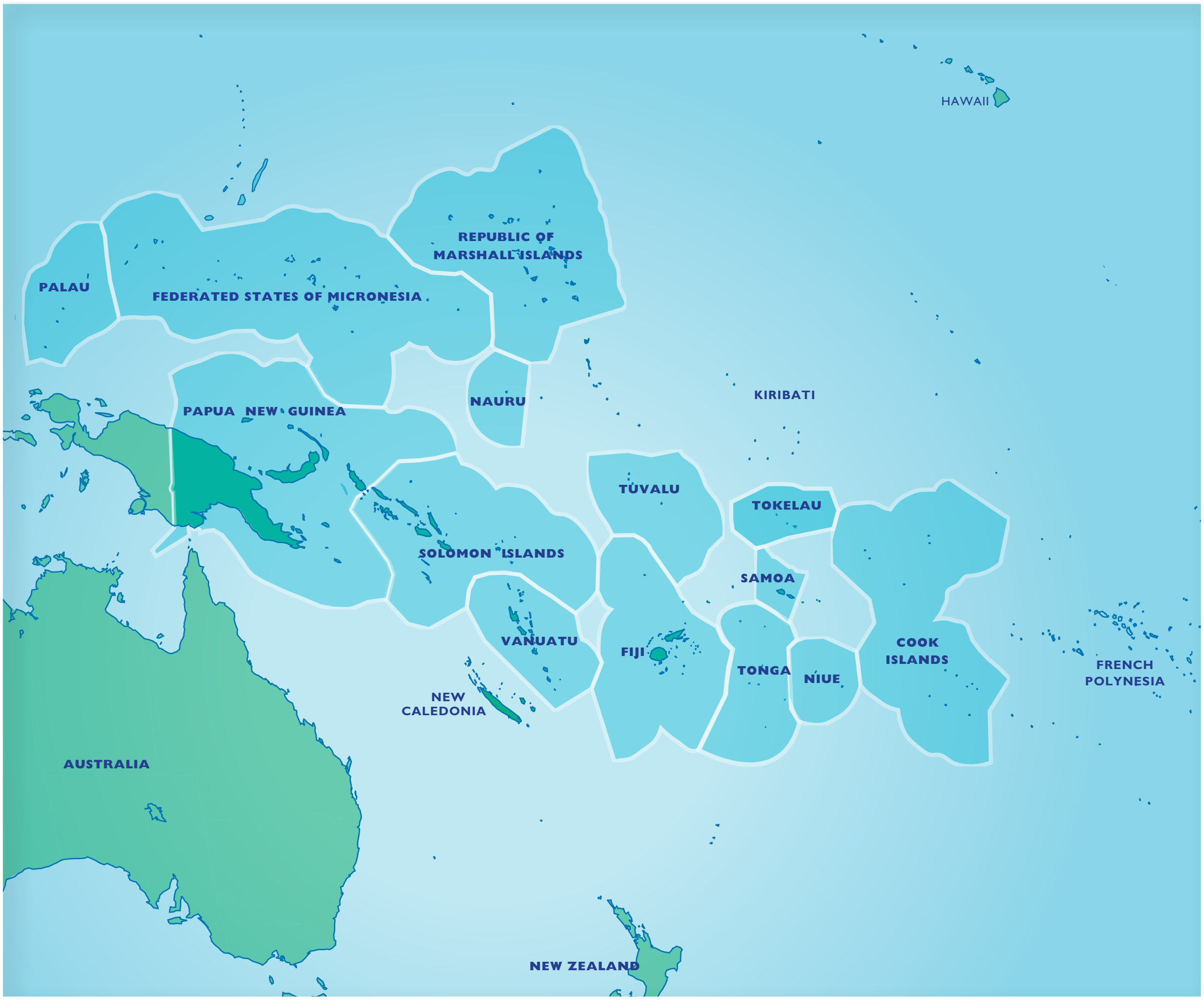
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ACKNOWLEDGEMENTS

Special thanks are extended to my colleagues Ms Marita Manley of the Secretariat of the Pacific Community (SPC) and later Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Ms Paula Holland of SPC's Applied Geoscience Division (SOPAC). Their expertise and goodwill were instrumental to the success of the PACC CBA work programme and very much appreciated.

Thanks are also extended to Gabor Vereczi (UNDP) and the PACC Regional Management Unit (Taito Nakalevu and Peniamina Leavai) for facilitating and supporting the PACC CBA work programme.

I would like to acknowledge the technical backstopping support provided for a number of the PACC cost-benefit analyses – thanks to Andrew McGregor (consultant), Kirsten Oleson (consultant), Marco Arena (UNDP Samoa), and Marita Manley (GIZ). Thanks also to Anna Fink (SPC), Adam Daigneault (LandCare Research NZ), Kalara McGregor (EarthSystems), Emily Gaskin (NOAA), and Angela Ambroz (MIT) for reviewing individual PACC CBA reports. Thanks also to the PREEN team, Anna Ross Wilks and Paula Holland from SOPAC, for helping to coordinate peer reviews.

And finally, I would like to acknowledge country commitment and the participation of national officials in the PACC CBA work programme. This was the most important part of the programme.

EXECUTIVE SUMMARY

This report has been developed to summarise and communicate the key outputs and learnings of the cost–benefit analysis (CBA) work programme undertaken as part of the Global Environment Facility's Special Climate Change Fund (GEF-SCCF)- and AusAID-funded Pacific Adaptation to Climate Change (PACC) programme.

Two related 'knowledge products' on CBA and climate change mainstreaming have also been prepared under the PACC programme. These are (i) PACC Technical Report No. 1, Informing climate-resilient development: the application of cost–benefit analysis CBA) in the Pacific Adaptation to Climate Change (PACC) programme – Experiences and lessons learned on capacity building (September 2013); and (ii) Mainstreaming climate change adaptation in the Pacific: A practical guide (July 2013). These documents are available via the Pacific Climate Change Portal (http://www.pacificclimatechange.net/) and the PACC webpages (www.sprep.org/pacc-home).

Additionally, a Pacific Guide to Cost–Benefit Analysis (forthcoming) has recently been developed by SPREP, SPC, GIZ, PIFS, LandCare Research NZ, and UNDP, and will also be available via the Pacific Climate Change Portal (http://www.pacificclimatechange.net/index.php/eresources/documents?task=showCategory&catid=121). The guide describes the basics of CBA within the Pacific context, and it is recommended that readers familiarise themselves with these basics before reading this technical report.

The PACC CBA work programme

The purpose of this work programme was to help improve selection and design of PACC pilot projects, as well as to build Pacific island country (PIC) capacity in the use of CBA. The PACC CBA work programme was the first (substantive) capacity building programme of its kind known to have been delivered to PIC governments.

Key elements of the PACC CBA work programme were:

1. Assembling multidisciplinary country teams to conduct PACC CBAs;
2. Training workshops and development of workplans to conduct CBAs of selected PACC pilot projects;
3. Ongoing technical support to help countries implement CBA workplans (i.e. conduct a CBA of their PACC pilot project); and
4. A conclusion workshop to help PACC officials effectively communicate CBA results and findings to decision makers, and to share findings and lessons learned from the CBA experience across PACC countries.

The technical components of the PACC CBA work programme aimed to strengthen the evidence base of pilot projects under the PACC programme in order to improve the quality of these projects. The intention was also to demonstrate how CBA can be used to help integrate climate risk considerations into project design so that projects are more effective at reaching their development objectives.

This report summarises each of the seven CBAs completed under the PACC programme. The key aim of these summaries is to provide PIC government officials with some practical insights and lessons learned on how to apply CBA to development projects in the Pacific context; and how to incorporate climate risk and uncertainty into these analyses. Full CBA reports for select PACC pilot projects will be available on the PACC website by November 2013.

The seven CBAs were carried out on projects in the following sectors and countries:

- three water sector pilot projects in Niue, Marshall Islands and Tuvalu;
- two agriculture pilot projects in Palau and Solomon Islands; and
- two coastal infrastructure projects in the Cook Islands and Samoa.

Approach

A standard procedure was used for each of the CBAs and is briefly described in this report. More detailed information can also be found in the forthcoming Pacific Cost-Benefit Analysis (CBA) Guide, which will be available at the following weblink: http://www.pacificclimatechange.net/index.php/eresources/documents?task=showCategory&catid=121.

Where feasible, climate risk considerations were incorporated using 'expected value analysis', also known as 'risk-based approach' or 'probabilistic analysis'. Climate change uncertainty was incorporated through sensitivity analysis of weather event probabilities. This report briefly outlines the basics of expected value analysis and sensitivity analysis, and also includes a brief description in Appendix 1.4 on how to use the Pacific Climate Futures Tool (Pacific Australian Climate Change Science and Adaptation Program, 2011) to derive future weather event probabilities.

In situations where data constraints prevented the use of expected value analysis, climate change risk and uncertainty was factored into the analysis through a more basic sensitivity analysis of project effectiveness (in achieving intended benefits). This is not the preferred way to integrate climate risk into CBA but is sometimes appropriate where there is a lack of data and/or if the project proposal is small-scale such that further effort and expense to collect data cannot be justified.

Success factors, challenges and lessons learned

In terms of planning and management of the CBA exercises, there were a number of aspects that worked well for the PACC CBA work programme and also a number that did not work so well.

The primary success factor was active participation by country officials. Where officials were interested and keen to be involved, this helped to ensure that available data and information was inputted to the analysis; officials understood the technical elements of the analysis and thus could communicate and discuss this analysis to stakeholders and decision makers (independent of technical support); and this knowledge was 'owned' and effectively used. Such active participation was significantly enhanced by technical assistance to implement CBA workplans being delivered over a longer period of time, rather than a short, one-off country visit.

A second related success factor was participation in the CBA by a multidisciplinary team including, for example, economists, meteorologists, engineers, sectoral planners, and environmental scientists. Among other things, where a functional multidisciplinary team was successfully set up, this helped to ensure important technical inputs from relevant fields were incorporated and that there was a broader understanding of the purpose and results of the CBA (and hence agreement on findings) among stakeholders. One part of the inter-disciplinary working arrangements that was reported to work well was the use of the CBA workplan template/tool developed for the PACC CBA work programme. This template is given in Appendix 1.2 of this report (and in the Pacific CBA Guide).

The key challenges were:

1. Late introduction of CBA into the PACC project. This meant that CBAs were too late to inform selection of some PACC pilot projects. It also meant there was little time available to complete the CBAs and communicate findings.
2. Lack of background assessments and data to input to the CBAs. For a number of the PACC CBAs, situational and problem-analysis-type assessments such as vulnerability assessments had not been completed prior to beginning the quantitative elements of the CBA. Also, in some cases relevant assessments and reports (secondary information) were known to exist but due to poor knowledge management systems within countries, could not be located for the analysis. Further, inadequate baseline data had been collected for PACC pilot projects wanting to undertake *ex-post* CBAs to evaluate their project (as opposed to *ex-ante* CBAs to appraise project options before implementation).
3. Difficulty attracting people with technical skills to participate in multidisciplinary CBA work teams. Most difficult to find were officials with an economics backgrounds. Engineers were also difficult to involve for some CBAs.

4. Limited number of days that some technical backstopping personnel, particularly consultants, were able to provide technical support to help participants conduct the CBA of their PACC pilot project.
5. Difficulties communicating CBA results. These difficulties were most evident where there was not strong technical expertise within PACC CBA teams (who did not have a sound understanding of the analysis undertaken) and where there was not ongoing technical support available for these activities.

Based on these experiences, a number of key lessons were learned:

1. *CBA must be introduced and planned for in the early stages of project development* if it is to effectively inform decision making on the selection and design of identified project options and approaches. This involves, among other things: educating stakeholders about the purpose of CBA and where it fits into the project cycle; budgeting for time and technical inputs needed to complete an appropriately detailed analysis; and scheduling activities and outputs to communicate the results/findings of the CBA to stakeholders and decision makers.
2. *Substantial effort is required to formulate multidisciplinary teams to oversee and conduct the CBA*. This should include technical officials such as economists, engineers, sectoral planners and meteorologists as appropriate. This is also important for ensuring that government officials understand the technical elements of the analysis; can communicate and discuss this analysis to stakeholders and decision makers (independent of consultant support); and this knowledge is 'owned' and effectively used.
3. *Good knowledge/information management systems within country governments (and CROP and regional development partner organisations) make the conduct of CBA far less resource and time intensive, and contribute significantly to more accurate (and hence useful) CBAs.* Increased involvement in the conduct of technical assessment reports by PIC government officials will increase ownership of reports which in turn is expected to improve management of this knowledge/information.
4. *Situational and problem analyses, such as vulnerability assessments, should be completed thoroughly and systematically prior to starting the quantitative aspects of CBA.* This helps to clarify the nature and causes of the project problem, and that identified options to address it are appropriate. This is needed to ensure the project objective is correctly specified and the CBA is thus correctly constructed. It is also needed to provide important input data and information to the quantitative aspects of the CBA.
5. *CBA provides an important 'gate-keeping' function.* The systematic CBA procedure serves to identify key data and knowledge gaps which are important for making sound, evidence-based decisions about project option selection and design. Adequate time is needed to allow for collection and analysis of such information gaps prior to project implementation.
6. *Adequate technical backstopping arrangements are critical*. To achieve ownership of assessments, technical backstopping should be provided with capacity building and skill development as a key focus – in addition to developing a robust CBA report. Ideally, country officials should lead on the conduct of analysis and report writing as much as possible, with technical backstopping guiding this process and providing 'review and comment' in a continuous and needs-based mentoring fashion. The use of detailed Terms of Reference (for in-kind support, CROP economists, consultants, or whoever) and the CBA work-planning tool can help ensure support meets the needs of countries. Technical support appears to be more effective (at producing better quality CBAs, achieving active participation by country government officials, and maximising country 'ownership' and use of CBA findings) if it is provided over a longer period of time so that country government officials have adequate opportunity to participate in the conduct of the analysis.
7. *Communication features should be a core and prominent part of future CBA exercises.* Adequate time and resources must be budgeted for communication activities. These include, but are not limited to: (i) preparing briefing papers on the CBA; (ii) delivering short presentations to decisions makers, including preparations to answer questions and defend the analysis; (iii) incorporating CBA information into Cabinet submissions; and (iv) incorporating CBA information into project proposal documents to be submitted to donors. These could be included as outputs of any technical support.

Areas for future work

It is hoped that PIC government officials can take on board relevant lessons from the PACC CBA work programme experience so that CBAs are more effectively applied in the future. This will help improve the evidence base and quality of development projects in the future.

For CBA to be more widely and effectively used by PIC governments, training of government officials and strengthening of institutional decision-making processes is also needed. PACC Technical Report No. 1, which describes experiences and lessons learned on capacity building under the PACC CBA work programme, suggests a number of ways to do this. A concept for a more systematic regional training programme on CBA is also currently under development, through the regional partnership established under the PACC CBA work programme.

Environmental valuation[1] studies for the Pacific region is another important area of future work. Information from these valuation studies are key inputs for many CBAs in the Pacific (and other related project assessment methods such environmental impact assessments, damage and loss assessments, etc.) but are not usually undertaken because they are time consuming and expensive. A more systematic and coordinated approach to conducting these studies in the region is needed with a view to eventually developing a pool of values that can be used for 'benefits transfer'[2] applications.

Finally, there may also be merit in extending CBAs from project-level assessments to sector-level economic analyses, in order to inform design of sector strategies, policies and plans. This level of analysis is a relatively new area of work for the Pacific region context and thus should be pursued on a trial or pilot basis. Water sector plans in atoll countries seem a very good first application given the magnitude of water scarcity and water quality problems in many PICs, especially in the context of climate change. Part of this should include economic valuation of water resources/water demands.

1 Environmental valuation techniques attempt to value environmental goods and services in monetary terms so they can be considered in decision-making and management.

2 Benefits transfer is a method of environmental valuation. It is a time-saving and cost-effective approach that uses economic values from previous environmental valuation studies and applies them to address current policy challenges.

GLOSSARY

Baseline	A measurement or description of a scenario used as a basis for comparison. In CBA, the baseline represents the best assessment of the world in the absence of the action (including government policies or regulations) proposed for assessment. This is sometimes referred to as the 'without' scenario
Benefit	Monetary or non-monetary gain received because of an action taken or a decision made
Benefit:cost ratio (BCR)	The ratio of the present value of benefits from an activity, expressed in monetary terms, relative to the present value of its costs
Benefits transfer	Benefits transfer is a method of environmental valuation. It is a time-saving and cost-effective approach that uses economic values from previous environmental valuation studies and applies them to address current policy challenges
Costs of production	Amounts paid for resources (land, labour, capital, and entrepreneurship) used to produce goods and services
Discount rate (r)	The rate at which future value of benefits and costs are adjusted to express them in present day values
Discounting	A method used where the value of future benefits and or costs is expressed as present day values
Environmental valuation	Economic techniques that attempt to value environmental goods and services in monetary terms so they can be considered in decision making and management
***Ex-ante* CBA**	A CBA undertaken while a project is still under consideration, before it is implemented
***Ex-post* CBA**	A CBA undertaken at the end of the project period to evaluate its performance/ success
Externality	A cost or benefit which results from an economic activity and which affects an otherwise uninvolved party
Net present value (NPV)	Sum of the discounted stream of benefits and costs over time. A positive NPV indicates the project option will confer a net gain to society and is thus a worthwhile allocation of resources.
Non-market benefits and costs	Benefits or costs arising from the production or consumption of goods/services that are not traded in markets and either have no monetary price or whose price does not reflect all the benefits and/ or costs
Sensitivity analysis	An assessment of how different values for one (independent) variable will impact on the results of the CBA
Project cycle	Standardised process that project managers use to design and implement evidence-based projects
Willingness to pay	The maximum amount a person would be willing to pay, forego or exchange in order to receive goods or a service or to avoid something undesired
With and without analysis	Comparison of the situation without the proposed activity (what would happen under the baseline scenario) and with the activity. The intent of 'with and without analysis' is to identify only the changes that are clearly associated with the project options, and not include changes that would have occurred anyway
With scenario	The best assessment of the situation if the action proposed for assessment is pursued
Without scenario	No change option. This the best assessment of the situation in the absence of the action proposed

INTRODUCTION

As part of the Global Environment Facility's Special Climate Change Fund (GEF-SCCF)- and the Australian Agency for International Development (AusAID)-funded Pacific Adaptation to Climate Change (PACC) programme, a cost–benefit analysis (CBA) work programme was delivered. The purpose of this work programme was to help improve selection and design of PACC pilot projects, and to help build Pacific Island country and territory (PICT) capacity in the use of CBA.

CBA is a systematic process for identifying, valuing and comparing costs and benefits of a projects. It can help inform decisions about whether to proceed with a project or not, which project option to implement, when best to implement, and/or what refinements can be made to improve project design.

CBA is also an effective way to help integrate climate risk considerations into project design, and to engage officials from planning and finance ministries on climate change related issues. This helps to make sure projects are more effective at reaching their development objectives.

In the Pacific region, CBA is in its early stages in terms of systematic application in development processes and government capacity needed, and its use is rather ad hoc. The Council of Regional Organisations in the Pacific (CROP) agencies and development partners have regularly used CBA to inform a large variety of project types ranging from small-scale agriculture pilots to large infrastructure investments to conservation. However, there is little CBA work actually being conducted (or overseen) by PICT governments and officials themselves.[3] Some PICTs do have project appraisal guidelines which include a section on describing and quantifying the costs and benefits of budget submissions, but staff typically do not have the knowhow and/or the confidence to undertake this work.

This report aims to provide PICT government officials with practical insights on how to apply CBA to development projects in the Pacific context, and how to incorporate climate risk into these analyses. It does this by:

1. Briefly describing the CBA framework used in the PACC CBA work programme;
2. Summarising the seven CBA studies completed under the PACC CBA work programme; and
3. Reporting key lessons learned on the planning and management aspects of the PACC CBA work programme.

This report is one of three interrelated 'knowledge products' on CBA and climate change mainstreaming prepared under the PACC programme; the other two are: (i) PACC Technical Report No. 1, Informing climate-resilient development: the application of cost–benefit analysis CBA) in the Pacific Adaptation to Climate Change (PACC) programme – Experiences and lessons learned on capacity building (September 2013); and (ii) Mainstreaming climate change adaptation in the Pacific: A practical guide (July 2013). These documents are available at http://www.pacificclimatechange.net/index.php/eresources/documents?task=view&id=737&catid=121 and www.sprep.org/pacc-home. These publications draw from the seven CBA country reports, which are key outputs of the CBA work programme.

A Pacific Cost–Benefit Analysis Guide has also recently been developed by SPREP, SPC, GIZ, PIFS, LandCare Research NZ and UNDP. The guide describes the basics of CBA within the Pacific context, and it is recommended that readers familiarise themselves with these basics before reading this technical report. The guide will be available at http://www.pacificclimatechange.net/index.php/eresources/documents?task=showCategory&catid=121.

3 Results from a needs analysis survey undertaken as part of scoping activities for the Pacific Cost-Benefit Analysis (CBA) Initiative, 2013.

Structure

This report is organised in five parts as follows:

Part 1 provides some background information on the PACC CBA work programme and outlines the broad CBA framework that was used.

Parts 2 to 4 summarise the CBAs completed under the PACC CBA work programme and reports success factors and key challenges from the planning and management aspects of each of these activities:

- Part 2 does this for the water sector PACC pilot projects in Niue, Marshall Islands and Tuvalu;
- Part 3 does this for the agriculture sector pilot projects in Palau and Solomon Islands; and
- Part 4 does this for the coastal zone management projects in Cook Islands and Samoa.

Part 5 summarises the success factors and key challenges from the planning and management aspects of each of the PACC CBAs and draws the most important lessons learned from the collective PACC CBA work programme experience. It also suggests areas for future work.

PART 1 CBA AND THE PACC PROGRAMME

1.1 Background

The PACC programme is a US$21 million, 5-year programme funded by GEF-SCCF and AusAID which began implementation in February 2009. It covers 14 PICTs and aims to reduce climate change and disaster risks at the community level in the water, food security (agriculture), and coastal sectors. It is implemented by designated national agencies in the 14 PICTs, with SPREP serving as regional implementing partner and UNDP as implementing agency.

The PACC programme design has three main components. These are 'mainstreaming' of climate change risk into relevant government processes, policies and strategies; piloting or demonstration of practical adaptation measures; and communication of climate change risk and lessons learned. More information on the PACC programme design can be found at http://www.sprep.org/pacc-home.

During the first three years of PACC implementation, it was found that some countries were experiencing problems appraising, identifying and designing adaptation options, and setting up monitoring and evaluation frameworks for their pilot projects. More specifically, it was found that:

- Some countries were experiencing difficulties selecting appropriate measures to implement as their pilot demonstration project;
- For some countries which had selected their project, it was not clear whether the option(s) selected were the most worthwhile ones to reduce the identified climate risk(s) and enhance resilience; and
- Some countries had not adequately set up data collection and monitoring frameworks to allow for robust evaluation at the end of the project (needed to inform decisions about project upscaling – the primary rationale for the piloting component of the PACC).

Reasons identified for the above-mentioned problems included a lack of guidance and a lack of capacity in-country to undertake adequate economic assessments of these projects.

To help address these problems, a decision was made at the second PACC Multipartite Review Meeting in 2011 to introduce a CBA work programme into the PACC.

The CBA work programme was intended to build capacity in CBA, as well as enable the carrying out of CBAs for the PACC pilot projects. The first component is described in the companion report, PACC Technical Report No. 1, on experience and lessons learned on capacity building for CBA in the PACC programme. This report focuses on the second component, the carrying out of the CBAs, and experiences and lessons learned in the process.

The primary aim of the second component of the CBA work programme was to improve the evidence base of pilot projects under the PACC, in order to improve the quality and outcomes of these projects. The secondary aim was to demonstrate how CBA can be used to help integrate climate risk considerations into project design; and to engage officials from planning and finance ministries on climate change related issues. This helps to make sure projects are more effective at reaching their development objectives.

The specific objectives of this component of the PACC CBA work programme were to:

- Increase PICTs' understanding of their PACC pilot project;
- Provide advice on selection and design of PACC pilot projects that are still under development; and
- Assist with monitoring and evaluation of PACC pilot projects.

Key elements of the CBA work programme were:

1. Assembling multidisciplinary country teams to conduct PACC CBAs;
2. Training workshops and development of workplans to conduct CBAs of select PACC pilot projects;

3. Ongoing technical support to help countries implement CBA workplans (i.e. conduct a CBA of their PACC pilot project); and
4. A conclusion workshop to help PACC officials effectively communicate CBA results and findings to decision makers, and to share findings and lessons learned from the CBA experience across PACC countries.

CBAs completed for the PACC CBA work programme aimed to be as simple as possible, whilst still being sufficiently accurate and reliable. This approach was taken in an effort to maximise PIC government official involvement in the conduct of the CBAs (to increase PIC government officials' knowledge and skills in CBA – the capacity-building component of the PACC CBA work programme) and to maximise understanding of the final CBA report. This approach was also appropriate given the small scale of the pilot projects being analysed. The key technical components of the PACC CBA work programme have now been completed.

A programme logic for the PACC CBA work programme is included in Appendix 1.1.

1.2. Overview of the CBA framework

CBA is a systematic process for identifying, evaluating and comparing costs and benefits of a project[4].

The aim of CBA is to help inform decisions about whether to proceed with a project; to choose which option to implement; and/or to improve project design. It is one of several tools that can be used to help this decision making.

The key features of a CBA are:

- All related costs (losses) and benefits (gains) of an action and/or decision are considered, including potential impacts on human lives and the environment;
- Costs and benefits are valued from a whole-of-society perspective, rather than just from one particular individual or interest group (that is, taking a public and not private perspective);
- Costs and benefits are expressed as far as possible in money terms as the basis for comparison;
- Costs and benefits that are realised in different time periods in the future are aggregated to a single time dimension (discounting); and
- Costs and benefits that are not monetised are still listed and considered during decision making.

The CBA process follows a logical and systematic sequence of analysis. For a basic CBA, this can be represented in up to seven key steps (Figure 1.1).

The sequence of steps is not necessarily rigid. CBA teams often find it necessary to return to previous steps as more data/information becomes available and the nature of the problem they are investigating becomes more evident.

The CBA procedure is described in detail in the Pacific CBA Guide, which will be available at http://www.pacificclimatechange.net/index.php/eresources/documents?task=showCategory&catid=121.

A CBA 'workplan' template was developed to assist PACC countries organise and conduct a CBA of their pilot project. This template essentially follows each step of the CBA procedure and outlines the types of information that will need to be collected and collated at each stage, as well as some of the key questions and considerations that should be given some thought. A copy of this template is available in Appendix 1.2 of this report (and also in the Pacific CBA Guide).

4 The project or projects in question may be public projects – undertaken by the public sector – or private projects. CBA can also be used to analyse the effects of changes in public policies such as the tax/subsidy or regulatory regimes. However a very broad range of issues can arise in this kind of analysis and, for ease of exposition, we adopt the narrower perspective of project analysis in this document.

FIGURE 1.1. Key steps of the CBA process

1 Determine the objectives of the analysis

Purpose – to clarify the questions the analysis seeks to answer. What decision does it seek to inform?

↓

2 Identify costs and benefits

Purpose – to clarify the potential impact of the activity and the type of costs and benefits it would generate

↓

3 Value costs and benefits

Purpose – as far as possible, to express the value of benefits and costs in monetary terms. Which of these values can be valued and how?

↓

4 Aggregate costs and benefits

Purpose – to specify the timeframe that is relevant for the analysis, the discount rate to be used, and calculate the net present value (NPV) of each option.

↓

5 Perform sensitivity analysis

Purpose – to assess the importance of major uncertainties associated with the analysis and activity

↓

6 Consider distributional impacts

Purpose – to consider who will incur the costs and benefits and what impact this might have on the activity

↓

7 Prepare recommendations

Purpose – to summarise how to proceed from here. Which option should be chosen and why?

1.3. Incorporating climate risk and uncertainty into CBAs

Risk

A key concept of climate change adaptation (and disaster risk reduction) is risk. Projects are considered to be risky if the value of a benefit (or cost) of the project depends, at least in part, on a random event. For example, an agriculture project faces a situation of risk at the beginning of the growing season at which time it is not known whether rainfall (a random event) will be sufficient to grow the planned crop (benefit) or not.

In the short term, the probability of having a sufficient amount of rainfall can be predicted using past weather observations. CBA can use this historical information to help make an accurate appraisal of whether a project proposal is worthwhile pursuing or not.

The best way to do this is by calculating the 'expected value' of relevant costs or benefits of the proposed project option – providing reliable historical weather information is available. This approach to incorporating climate risk is also sometimes called 'probabilistic analysis' or 'risk-based approaches'. An illustration of expected value analysis is provided in Appendix 1.3.

Climate change and uncertainty

In the medium to long term, probabilities or likelihoods for weather events occurring (e.g. low levels of rainfall) are expected to change due to climate change. However, the extent – and direction for some climate variables such as rainfall – of this change is unknown. That is, the probabilities of future weather events in the medium to long term are uncertain.

The reason for this uncertainty is, among other things, (i) global climate models do not know with a sufficient degree of confidence by how much temperature and precipitations will increase from a given increase in greenhouse gas emissions, and (ii) global climate models are limited in their ability to predict climate at the regional or local level (UNDP, forthcoming). The further into the future we look, the greater this uncertainty is.

It is important that appraisal of medium or long-term projects take this uncertainty into account – because changes to weather can have significant implications for the success of projects, and if not properly considered can significantly reduce its effectiveness and can lead to 'maladaption'. In CBA, this can be done by applying 'sensitivity analysis'.

The sensitivity analysis procedure used in the PACC CBA work programme was to recalculate the expected value of project benefits (or costs) using weather event probabilities corresponding to different future climate change scenarios. The purpose of this sensitivity analysis was to see if the results of the CBA materially change when we change weather event probabilities and hence whether our view of the project proposal changes.

The practice of the sensitivity analysis procedure for climate uncertainty is illustrated in Appendix 1.3.

Estimates for weather event probabilities

For the PACC CBAs, estimates for weather event probabilities were based on climate projections provided in the Australian Government's Climate Change in the Pacific: Scientific Assessment and New Research country reports (2011) – http://www.pacificclimatechangescience.org/publications/reports/.

Estimates were also informed by advice from country Met Offices and the SPREP Met desk. Country Met Offices used the Climate Futures Tool to formulate their advice. More information on the Climate Futures Tool, which has been developed as part of the Australian Government's Pacific Climate Change Science Program (PCCSP), is available at http://www.pacificclimatefutures.net/.

In some PACC CBAs, the relationship between climate variable and the project cost/benefit was not well understood, due to a lack of data and information. As such, it was not possible to incorporate climate risk into the CBAs explicitly through sensitivity analysis of different weather event probabilities. In these cases, climate risk was incorporated through a more basic sensitivity analysis of the effectiveness of the option in generating intended benefits. This is not the preferred way to integrate climate risk into CBA but is sometimes appropriate where there is a lack of data and/or if the project proposal is small scale (such that further effort and expense to collect data cannot be justified).

A brief illustration of how the Climate Futures Tool can be used to determine a range of plausible weather event probabilities for use in CBA sensitivity analysis is provided in Appendix 1.4. It is recommended that practitioners use the Climate Futures Tool for this purpose. Country Met Offices can assist with this.

1.4. Causes and drivers of a given (project) problem

An emphasis of the CBA work programme was also to make sure the range of causes and drivers contributing to a given (project) problem were properly considered . This includes climate drivers such as potentially increasing frequency and length of drought events, but importantly, it also includes non-climate causes and drivers of the problem.

An example of a non-climate related cause contributing to water scarcity problems in PICT atoll countries is inadequate pricing and regulation of public water supply services. Inadequate pricing (or lack of pricing altogether in some cases) does not provide the necessary incentives for households to efficiently manage their water consumption, leading to wastage and sometimes even increasing water dependencies and vulnerability.

It is important that the range of causes and drivers of a given project problem – both climate and non-climate related – are properly considered and understood. If they are not, then there is a good chance the project objective will not be correctly specified; project options identified may not be appropriate; and/or options may not be optimally designed so they are effective at achieving their intended outcomes/benefits. Similarly, if all important causes and drivers of a given project problem are not properly understood in the CBA then results of the CBA may be inaccurate and could lead to incorrect conclusions and recommendations.

To help facilitate due consideration of the range of causes and drivers relevant to a given project problem, the PACC CBA work programme undertook a number of activities/measures. These were:

- Set up multidisciplinary teams, with different perspectives and skill sets, to plan for and conduct the PACC CBAs;
- Delivered brief training sessions on problem analysis as part of the sub-regional CBA training workshops; and
- Developed and utilised CBA workplan templates which contain a 'problem statement' section which has a climate and non-climate causes and drivers sub-section.

PART 2 WATER SECTOR PACC CBA SUMMARIES

CBAs were conducted for three water sector PACC pilot projects. These were the Niue, Republic of the Marshall Islands (RMI) and Tuvalu projects.

The Niue and RMI CBAs were undertaken prior to project implementation. The objective of these CBAs therefore was to inform selection and design of pilot measures to be progressed under the PACC.

The Tuvalu CBA on the other hand was undertaken part way through project implementation – as construction of the pilot measure was nearing completion. The objective of this CBA was to inform possible complementary measures in order to maximise the benefits of the project; and to help set up a more robust monitoring and evaluation framework to provide for quantitative evaluation at the end of the project (through an ex-post CBA). The Tuvalu CBA also had a very strong capacity building (i.e. knowledge and skills in CBA) focus.

The CBA summaries below are simplified versions of the full CBA reports, to facilitate understanding and learning.

2.1. Niue

Problem statement

The groundwater lens is the primary source of freshwater in Niue. Due to the permeable nature of the coral structure, this lens is considered to be highly vulnerable to surface land use activities (SOPAC, 2007a).

To date, there have only been a few minor groundwater quality incidents reported (Mosley and Carpenter, 2005) and nothing has happened which has resulted in recorded water-related disease or sickness, or long-term interruptions to groundwater supply services. However, the chances of contamination occurring could increase in the future and the consequences of this would be significant.

Causes and drivers of the problem

Broadly speaking, groundwater contamination risks are expected to increase in the future if land use activities increase (such as the resumption of extensive taro exporting) and groundwater supply infrastructure – notably pipes – continues to deteriorate (Siohane and Chapman, 2009). Underpinning these risks is inadequate regulation of land pollution (pollution externalities) and poor financial management. Inadequate pricing of public groundwater supply services also contributes to this problem as it acts as a disincentive for private augmentation of water supply infrastructure (e.g. through household rainwater tanks).

Contamination risks may further increase in the medium to long term under the effects of climate change – specifically if the probabilities of cyclone and/or extreme rainfall events increase. When these events occur, there is an increased chance that surface contaminants will enter the groundwater lens and (cracked) pipes and degrade water quality. The Pacific Climate Change Science Program (PCCSP) Scientific Assessment Report (2011) predicts that extreme rainfall will likely increase (by 13%) in Niue by the year 2055. The PCCSP report further projects a reduction in cyclone frequency and intensity from its historical average of 15 tropical cyclones per decade, though these projections are highly uncertain.

Options

The Niue Government has identified household rainwater tanks as a measure to help reduce risks to water supply quality and improve water supply service reliability. Household rainwater tanks provide an alternative source of freshwater supply and also reduce households' reliance on the public water supply system.

Two rainwater tank options have been identified; (i) a 5,000 litre high-density polyethylene (HDPE) tank and (ii) a 10,000 litre HDPE tank.

Under the original PACC design, this project is intended to be a demonstration project. The rationale is for this demonstration to provide information and thus confidence for the private sector to then replicate the provision of household rainwater tanks.

Costs and benefits

The costs considered in the CBA related to setup and operation of household rainwater tank options. The estimated cost of the proposal was between NZ$5,894 and NZ$6,557 for the 5,000 litre tank and between NZ$6,881 and NZ$7,544 for the 10,000 litre tank option. The costs covered in the CBA included the following:

- purchase of tank;
- installation costs;
- gutters and fascias;
- first flush device and downpipes; and
- maintenance costs.

The benefit streams were considered as four separate categories.

The first category related to reduced health impacts/risks from groundwater supply contamination events. This was approximated as the medical costs and lost income that would be avoided if household rainwater tanks were installed and used (which would provide access to good quality drinking water during groundwater contamination events) relative to the business-as-usual scenario (where households continue to rely almost exclusively on groundwater sources for potable water supply). The value of medical costs avoided was calculated by multiplying the expected number of water-related sickness cases avoided – differentiated as mild and serious – by the unit costs per medical treatment (comprising medical consultation NZ$150 plus hospital stay NZ$500; figures from Niue Health Department in 2010). The value of lost income avoided was calculated by multiplying the expected number of water-related sickness cases avoided – again differentiated as mild and serious – by the number of days that persons have to take off work when sick (1 and 3 for mild and serious respectively; estimate provided by Niue Health Department in 2010), by the average wage rate (NZ$80 per day, according to the Household Income and Expenditure Survey carried out in 2002). The number of water-related sickness cases avoided was approximated at 50% of incidents expected in the business-as-usual scenarios developed by Talagi (2011). A summary of this scenario is provided in Appendix 2.1.

The second benefit category related to improved water supply reliability. The value of this improvement in water reliability was approximated as the time saved by householders spent collecting water from reservoir tanks and time saved by Public Works Division (PWD) staff managing rationing of water at village reservoirs. The value of this improvement in water reliability further considered the avoided cost of householders purchasing storage containers to hold water during supply interruptions (approximated at NZ$15 per household per year based on market survey). The value of time saved was calculated by multiplying the number of hours saved by the average wage rate of NZ$15 per hour (Household Income and Expenditure Survey, 2002; Talagi, 2011). The expected period of time saved from the household rainwater tanks corresponds to 100% of the average supply interruptions observed historically.[5]

The third benefit category considered was reduced water pumping costs associated with reduced use of groundwater. Where the introduction of household rainwater tanks leads to reduced demand for groundwater,

5 The frequency of water infrastructure (regular) maintenance in each village is once per year and lasts for 2 days (Clinton Chapman, personal communication, May 2012). The frequency of power outage interruptions is approximately six times per year and lasts for 6 hours (personal communication, Director Power Authority, 30 May 2012). In addition, when cyclone events occur, the power supply systems are shut down as a precautionary measure. This results in short-term water supply interruptions for an average of 4 days (Clinton Chapman, personal communication, July 2012), 1.5 times per year (PCCSP, 2011). Power-related water supply interruptions only affect households located in upper terrace areas where water supply systems are pressure-pumped (a gravity fed system is not feasible). During this time, affected households must collect water rationed directly from the village tank/reservoir, which is an inconvenience.

variable pumping costs of providing groundwater supply services would be reduced. Note, no infrastructure costs would be offset as there is little scope to down-size infrastructure and still provide groundwater supply services (with the possible exception of village storage tanks/reservoirs). The total public water supply costs avoided were calculated by multiplying the quantity of offset water by the variable cost of providing groundwater supply services. The quantity of groundwater expected to be offset was assumed to equal the water produced from tanks (0.100 megalitres (Ml) per year and 0.093 Ml per year for a 10,000 litre and 5,000 litre tank respectively)[6] which was based on estimates made in the technical design document (Chapman, forthcoming). Variable costs are taken to be electricity costs of pumping (NZ$444/Ml)[7] plus the carbon costs (NZ$54/Ml)[8] associated with this electricity generation.

Finally, the benefit from potentially reduced imports of bottled water was considered. The expected reduction of imports of bottled water resulting from the introduction of household rainwater tanks was approximated to be 50% of current average household levels (approximately 20 litres per year, increasing at 3% per annum)[9]. The value of this expected reduction in bottled water imports was calculated by multiplying the quantity of bottles reduced by the market price for that water of NZ$2/litre bottle (Talagi, 2011).

Results and sensitivity analysis

Once the costs and benefits of the project options were quantified, the data were used to determine the net benefit of the proposal. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 2.1A below. Note: the NPV results are in year 2012 New Zealand dollar values and the rainwater tanks are assumed to function for 20 years. Further note that NPVs and BCRs calculated are for rainwater tanks on households located in upper terrace areas.

TABLE 2.1A. Niue PACC CBA results

	Economic results	
	5,000 litre HDPE rainwater tank	**10,000 litre HDPE rainwater tank**
(1) Present value of costs at 4% discount rate	$6,058	$7,006
(2) Present value of benefits at 4% discount rate		
Improved water supply quality	*$153*	*$153*
Improved water supply reliability	*$4,763*	*$4,763*
Avoided pumping costs	*$835*	*$895*
Avoided imports of bottled water	*$445*	*$445*
	$6,196	$6,256
(3) NPV = (2) – (1)	$138	**–$750**
(4) BCR = (2) / (1)	1.02	**0.89**

6 This is the estimate used for a modern sized house with a target rate of supply of 100 litres/day/person, average household size of 3.06 persons and a failure rate of supplying the target rate of 10.4% and 16.4% for 10,000 and 5,000 litre tanks respectively.
7 Electricity costs of pumping are estimated by dividing the total electricity cost for water pumping excluding fuel tax budgeted for 2011 of NZ$121,764 (10-11 Budget for Water Works Division) by the total quantity of water pumped in 2006 of 274 ML (WBWC/SOPAC 2007, Niue Water Benchmarking document, Chapman, Talagi (2011)).
8 Carbon costs are estimated at NZ$54/ML and are taken from Ambroz (2009).
9 Kimray Vaha, Statistician, personal comm., April 2010, see p.30 Talagi (2011)

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the future groundwater supply contamination scenario to account for the many uncertainties relating to this including climate risks (see Appendix 2.1); (ii) effectiveness of rainwater tanks in mitigating health incidences (a reduction in the effectiveness of tanks in mitigating health incidences from 50% to 25%); (iii) expected useful life of rainwater tanks (a reduction from 20 years to 10 years); and (iv) value of time (a reduction from NZ$15/hour to NZ$7.50/hour). The sensitivity analysis results for a 5,000 litre HDPE tank are presented in Table 2.1B below.

TABLE 2.1B. Niue PACC CBA sensitivity analysis results for a 5,000 litre HDPE tank

Variables	Primary results		Sensitivity test results	
	NPV ($)	BCR	NPV ($)	BCR
(i) Future groundwater contamination scenario	$138	1.02	$62, $213	1.01, 1.04
(ii) Effectiveness of rainwater tanks in mitigating health incidences (% reduction in incidences)	$138	1.02	62	1.01
(iii) Expected useful life (years)	$138	1.02	–2,107	0.63
(iv) Opportunity cost of time ($/hour)	$138	1.02	–2,126	0.65

Conclusions

Overall, the results of the analysis indicate that household rainwater tanks may be a worthwhile demonstration project to be implemented under the PACC project, providing demonstrations focus on 5,000 litre storage capacity – 10,000 litre tanks were not shown to confer net economic benefits.

The sensitivity analysis results also highlight the importance of implementing complementary measures to make sure project benefits are fully realised. Of particular note, sensitivity (iii) shows that 5,000 litre tanks will generate a large net cost if the tank only lasts for 10 years rather than 20 years – as would be expected if households do not properly maintain and care for rainwater tanks. To incentivise households to properly use and look after their rainwater tank, water tariff reforms for public (ground)water supply services should be introduced, consistent with the Niue National Strategic Plan (2009–2013). Also, awareness and education measures should be implemented to address other information failures constraining use (the private uptake) of rainwater tanks such as perceived health risks of tanks.

A further complementary measure that should be considered is strengthened regulation of land-based pollution, as is being piloted under the Integrated Water Resource Management (IWRM) project. Land pollution 'externalities' are a key cause of potential water quality problems and are not directly addressed by demonstration of household rainwater tanks.

Finally, and perhaps most importantly, the number of rainwater tanks implemented under the PACC project should be small. This is consistent with the rationale of government/donor intervention, which is to demonstrate household rainwater tanks so that the private sector can uptake and replicate. Large-scale government provision of rainwater tanks to households is inappropriate in this context because (i) household rainwater tanks have large private benefits and public aid will 'crowd-out' private investments[10] with no net social benefit; and (ii) there is a well-functioning welfare system in Niue to address equity issues.

10 There is a private provider of rainwater tanks based in Niue which sell tanks at comparable prices and quality to New Zealand markets.

Success factors , key challenges and outcomes of CBA implementation

SUCCESS FACTOR 1 – A key enabler of the CBA was active participation and contributions from the water engineer based at the Niue PWD. Technical inputs and reports provided by the engineer added significantly to the accuracy and hence usefulness of the CBA.

SUCCESS FACTOR 2 – Another key enabler was easy access to CBAs and other technical reports previously completed by SPC-SOPAC for the Niue water sector. Most of these technical reports are available on the SOPAC website.

CHALLENGE 1 – CBA was introduced late into the project development cycle. By the time CBA was started, political commitment had already been made for the Niue Government/PACC to provide rainwater tanks to the entire Niue population.

OUTCOME 1 – The Niue Government took on board the advice of the CBA to focus on 5,000 litre tanks rather than 10,000 litre tanks. However, because the Government had made a political commitment to provide rainwater tanks to the entire population, it did not agree to the CBA report recommendation to keep the demonstration of household rainwater tanks small scale.

2.2. Republic of the Marshall Islands

Problem statement

Water supply to households in the Rairok and DUD area of Majuro is provided from a mix of public (operated by Majuro Water & Sewer Company (MWSC)) and private (household rainwater tanks) systems. MWSC's main source of this supply is the airport catchment. Water collected from this source is stored in reservoirs, treated using sand filtration and chlorination, and then pumped to the Rairok and DUD area via a 16 km distribution pipe.

Water supply (both from the public water supply system as well as private rainwater tanks) in DUD-Rairok is considered to be inadequate to meet community needs. While data gaps prevent precise quantification, conservative estimates of current supply and demand (of 150 litres per household per day[11]) indicate there is a shortfall in supply of at least 253,000 m^3 per year during normal rainfall years (rainfall is 3.3 metres per year; SOPAC, 2007). During drought years, the water scarcity problem is much more significant. Optimistic estimates (assuming all existing storage capacity is available and is operating at 100% efficiency) suggest there is sufficient water storage to meet about 47 days of demand. This would be enough to get the area through most historical drought periods. More realistic estimates (including the assumption that distribution system losses cause 50% inefficiency in public system) indicate there is more like 28 days of water on hand.

A survey undertaken by the Marshall Islands Economic Policy, Planning and Statistics Office (2010), reported that nearly half of households say they face water scarcity "often" and 42% reported "sometimes". Water shortages have been blamed for increased incidents of gastroenteritis, pink eye, and even a typhoid outbreak (EPPSO, 2010).

Causes and drivers of the problem

Some of the key causes and drivers of the water scarcity problem are:

- inadequate pricing and charging (SOPAC, 2007b; USAID, 2009);
- lack of public awareness (SOPAC, 2007b; USAID, 2009);
- inadequate regulation of MWSC;
- lack of capacity within MWSC (SOPAC, 2007b); and
- rural–urban migration and population growth at Majuro.

11 Per capita water demand is reported between 33–45 gallons per day (SOPAC, 2007b; EPPSO, 2010), although this range seems unsubstantiated by any household studies or data.

Climate change may also contribute to the Majuro water scarcity problem in the future through a number of potential effects.

Extreme tide events. Saltwater incursion into airport catchment and reservoirs (as well as the pump stations and treatment plant) associated with extreme sea level/high tide events degrades infrastructure and water quality and thus reduces yields (ADB, 2011). The PCCSP (2011) projects with "very high confidence" that sea level rise near RMI will increase by between 5 and 15 cm by 2030 under medium and high emission scenarios. This in turn is expected to contribute to increased frequency and extent of inundation events.

Changing rainfall patterns and drought events. Changing rainfall patterns and drought events may also impact on water availability in Majuro, though best-available modelling suggests that future changes are most likely be in the positive direction. The PCCSP (2011) predicts that the most likely future rainfall and drought scenarios in RMI through to 2030 will be no or little change. After 2030, PCCSP reports with "moderate confidence" that dry-season rainfall will increase by greater than 15% and the frequency of drought events will decline.

Options

The RMI PACC identified five possible options to address the water scarcity problem in DUD-Rairok, drawing on previous work and suggestions from the ADB (2011) and USAID (2009). These were:

Reduce losses at (airport) storage facility

1. Reline storage reservoir
2. Install evaporation cover on storage reservoir

Reduce losses in distribution system

3. Repair and/or replace leaking distribution pipes

Improve catchment efficiency and ability of airport runway catchment to withstand extreme tide events

4. (a) Improve maintenance of pressure release valves in airport runway and (b) repair cracks in runway

Increase size of airport capture to increase supply

5. Put in system to capture water from planned expansion of runway. For this option, two different construction material options were considered: (a) geomembrane and (ii) asphalt.

A sixth option to increase the number of households with rainwater tanks was also identified as another option and was assessed in the CBA. The analysis of this option is not presented here in the interest of keeping the summary succinct and simple.

Costs and benefits

The costs considered in the CBA were construction and maintenance costs. Both construction and maintenance costs included capital, equipment, materials, and labour. Details of construction and maintenance costs for each option is provided in Appendix 2.2.

The benefit streams were considered as two main categories.

The first category related to the benefits from additional water supply. This was estimated simply as unit value multiplied by the quantity of additional water supplied.[12] Due to a lack of data to estimate the true economic value of water, the unit value of water was approximated using the regulated residential water tariffs[13] ($1.03/

12 This approach is justified by the pilot project being a relatively small-scale project and so is not expected to change the level of communities willingness to pay for water.

13 Note, in general, the full-cost recovery of providing public water supply services is a better proxy for the true value of water in periods of no shortage than the regulated water tariff. However, the full-cost recovery unit amount could not be obtained from MWSC in the time available for this consultancy. As discussed below, a sensitivity test was run on this parameter to test how this influences results.

m³; from MWSC) and the market price of reverse osmosis-purified water sold by private sector businesses ($264/m³; from a market survey in2012), i.e. 'proxy' values. The unit value applied was differentiated for periods: (i) when there is adequate rainfall to meet demand through existing water supply infrastructure (taken to be non-drought periods); and (ii) when there is inadequate rainfall to meet demand through existing water supply infrastructure such that households must supplement public water supply (taken to be drought periods). The quantity of additional water supplied from each option, and how this was calculated, is summarised in Appendix 2.2. The proportion of additional quantities of water supply expected to be consumed in drought periods, and thus valued at the 'scarcity' rate, was calculated as the proportion of months in the next 20 years that are expected to be 'moderate' or 'severe' drought months (0.04375).[14]

The second benefit category related to lower incidences of water-related health problems such as gastroenteritis. Where community members fully understand the health risks of drinking poor quality or insufficient water and where health services are not significantly subsidised (such that individuals consider the full cost of health services in their decisions to purchase water), then the value of water estimated in the first benefit category should capture most of the health-related benefits of additional water supply. However, in practice these conditions do not sometimes hold and so some proportion of health benefits from additional water supply should be considered separately. In this study, lack of data/information and time constraints did not allow this benefit category to be quantified. Suffice to say, lower incidence of water-related health problems is considered to be a significant benefit of the project options.

Results and sensitivity analysis

Once the costs and benefits of the project options were quantified, the data was used to determine the net benefit of the proposal. This net benefit is expressed in terms of Net Present Value (NPV) and Benefit Cost Ratio (BCR). The results are presented in Table 2.2A below. Note: the NPV results are in year 2012 US dollar values.

TABLE 2.2A. Marshall Islands PACC CBA results

	Economic results						
	1. Reline reservoir	2. Evaporation cover	3. Repair and replace leaking pipes	4. Airport runway maintenance		5. Expand airport catchment	
				(a) Valves	(b) Cracks	(a) Geo-membrane	(b) Asphalt
(1) Present value of costs at 4% discount rate	125,130	53,383	2,029,619	56,026	135,345	801,510	2,024,658
(2) Present value of benefits at 4% discount rate							
Additional water supply	10,829,855	1,019,567	18,805,024	205,111	490,446	3,471,456	3,471,456
Improved health	*Not valued*	*Not valued*	*Not valued*	*Not valued*		*Not valued*	
	10,829,855	1,019,567	18,805,024	205,111	490,446	3,471,456	3,471,456
(3) NPV = (2) – (1)	10,704,724	966,185	16,775,406	149,085	355,101	2,669,947	1,446,799
(4) BCR = (2) / (1)	86.55	19.10	9.27	3.66	3.62	4.33	1.71

14 The PCCSP report (2011) predicts that 'moderate' and 'severe' droughts in RMI will occur 2.5 and 1 times in the next 20 years respectively and that an average drought in RMI lasts for 3 months. The proportion of water supply that will be consumed during drought periods can thus be calculated as (2.5 + 1)/20 x 3/12 = 0.04375.

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Some of the key variables/assumptions tested were: (i) unit value of water during non-drought periods (tested effect of assuming cost recovery value of water is US$1.55/m^3, which is 1.5 times the tariff rate for residential water customers); (ii) unit value of water during drought periods (tested effect of assuming scarcity value of water is $US10.30/m^3 – 10 times the residential tariff rate for residential water customers – rather than market price of reverse osmosis-purified water of US$264/m^3) (iii) proportion of additional water supply from options 4 and 5 which is valued at the scarcity rate (modelled as increasing from 0 to 0.0475 consistent with options 1, 2 and 3[15]); (iv) expected future rainfall (assumed future rainfall will be closer to historical lows than mean, i.e., 7.98 mm/day annual average instead of 9.21); and (iv) length of project life ((from 30 to 20 years for reservoir liner; from 30 to 20 years for evaporation cover; and from 5 to 10 years for geomembrane). Results of the sensitivity analysis are given in Table 2.2B.

TABLE 2.2B. Marshall Islands PACC CBA sensitivity analysis results

	OPTION 1 Reline reservoir	OPTION 2 Evaporation cover	OPTION 3 Repair and replace leaking pipes	OPTION 4 Airport runway maintenance		OPTION 5 Expand airport catchment	
				(a) Valves	(b) Cracks	(a) Geo-membrane	(b) Asphalt
(i) Unit value of water during non-drought periods is 1.5 times residential market price	11,130,204 (89.95)	1,006,241 (19.85)	17,514,212 (9.63)	251,640 (5.49)	600,324 (5.44)	4,405,675 (6.50)	3,182,527 (2.57)
(ii) Unit value of water during drought periods is 10 times assumed non-drought value	849,938 (7.81)	63,383 (2.19)	124,025 (1.06)	149,085 (3.66)	355,101 (3.62)	2,669,947 (4.33)	1,446,799 (1.71)
(iii) Proportion of additional water supply from options 4 and 5 that is valued at scarcity rate (0.0475 instead of 0).	10,704,724 (86.55)	966,185 (19.10)	16,775,406 (9.27)	2,127,241 (38.97)	5,833,306 (44.10)	41,445,566 (52.71)	40,222,418 (20.87)
(iv) Expected future rainfall is 7.98 mm/day, consistent with historical lows	10,704,724 (86.55)	966,185 (19.10)	16,775,406 (9.27)	123,374 (3.20)	345,583 (3.55)	2,234,794 (3.79)	1,011,646 (1.50)
(v) Length of project life is: – 20 years for liner – 20 years for evaporation cover – 10 years for geomembrane airport extension	8,386,665 (68.18)	5,338,902 (15.04)	16,775,406 (9.27)	123,374 (3.20)	345,583 (3.55)	3,020,408 (7.70)	

NB: NPV of costs for geomembrane is 451,048 when expected useful life is extended from 5 years to 10 years.

It is important to also note that options 1,2, 4 and 5 all assume that repair and replacement of leaking pipes (i.e. option 3) will be implemented. If this option is in fact not implemented then the benefits from each of the other options will be halved.

15 One could argue that the scarcity value should also be applied to options 4 and 5 because the saved water might fall prior to a drought, be stored, and then consumed in drought periods.

Conclusions

The preliminary results of the analysis undertaken to date indicate that all options will generate a net benefit for the RMI community. However, because there is a budget constraint for the PACC of some US$800,000, there is a need to prioritise options.

The preliminary results of the central CBA analysis suggest the following combination of options will generate the greatest net benefits for the DUD-Rairok community:

1. Install new liners
2. Install evaporation cover
3. Fix portion of pipeline

However, the sensitivity analysis shows that this result/ranking does not hold true if we change the assumption made about the scarcity value of water and the proportion of water produced from options 4 and 5 that will be consumed during drought periods (thus valued at the premium rate). If the alternative assumptions are in fact closer to reality, then options 5a and 4b and c are more attractive than option 2.

If more funding for water supply options in RMI is not expected to become available in the near future (such that lower ranked options will not be implemented), then some further research on the above variables[16] may be warranted before going ahead and selecting the preferred options. Note that further research on the true scarcity value of water in RMI is beyond the scope of this CBA, and the RMI PACC project. It is however an important area of future research, and more effort should be made in this regard.

Conversely, if more funding for water supply options in RMI is expected, then it is considered satisfactory for the above measures to be progressed without undertaking substantial further data collection activities. The CBA indicates these options represent a worthwhile use of resources, even with existing uncertainties, and should be pursued if more funding becomes available. This CBA can be used as one part of the evidence base to support the case for funding these options.

Demand-side measures should also be a focus of future water sector policies and projects, including education and awareness and pricing reforms. Demand-side measures help to provide the correct incentives needed for efficient use of water, and so that supply side measures are effective in reducing community vulnerability.

Success factors , key challenges and outcomes of CBA implementation

CHALLENGE 1 – One difficulty experienced for the RMI PACC CBA was that there was very little time permitted to conduct the analysis and to effectively communicate its findings and recommendations. This was because: (i) the RMI PACC had been slow to progress its pilot project and was now under pressure to start implementing; (ii) the CBA had not been properly planned for at the inception of the PACC project; and (iii) there were limited financial resources available to support (longer term) technical assistance. This meant that the CBA was required to start before the vulnerability assessment (assessment work that ordinarily precedes, and is inputted to, CBA); there were some other data gaps (e.g. full cost recovery of water supply services) still remaining in the final CBA report; and that communication of CBA method and results/findings to the range of stakeholders was not as thorough as it perhaps should have been.

CHALLENGE 2 – One other difficulty was that the core CBA team formed to conduct the RMI PACC CBA did not include any technical government officials, such as water engineers. Among other things, this is important for ensuring that government officials understand the technical elements of the analysis; can communicate and discuss this analysis to stakeholders and decision makers independent of consultant support; and this knowledge is 'owned' and effectively used.

16 The proportion of water from options 4 and 5 that will be consumed during drought periods is an area of uncertainty that can be cleared up from a small amount of further research. Other information that could be collected to develop a more accurate CBA include the full cost recovery of water services provided by MWSC and more detailed costings for each option.

OUTCOME 1 – The MWSC and the RMI PACC team took on board the advice of the CBA to implement options 1, 2, and 3. These options are now being implemented. Additional funding for water supply options on RMI is also becoming available as part of PACC+ (AusAID contribution to the programme) and potentially other projects. The PACC CBA is also being used as part of the body of research and evidence to support the case for these options.

2.3. Tuvalu

Problem statement

The primary source of freshwater in Lofeagi village, Tuvalu is rainwater collected using household rainwater tank systems. However, during a typical rainfall year, household rainwater tanks are dry for around 120–150 days (4–5 months). During drought years, this period is even longer.

When these water scarcity situations occur, households must purchase their water from expensive desalination plants or the limited bottled water. Tuvalu Government also provides two buckets (around 20 litres each) per day per household (using water collected from rainwater capture systems on government buildings) to poorer households (78% of the population).

In addition to the high cost of desalination water production, delivery of desalination water also involves long delays (up to 2 days) and associated inconveniences. Further, although robust empirical information is not available to demonstrate the extent of impacts, water scarcity (and poor water quality) is considered to contribute to some health problems experienced in Tuvalu such as diarrhoea (Lal et al., 2006).

CAUSES AND DRIVERS OF THE PROBLEM

Some causes and drivers of the water scarcity problem are:

- Poorly defined roles and responsibilities for household rainwater collection. For example, during the 2011 drought the majority of households thought that is was not their responsibility to clean their gutters and fix their roofs. This in turn provides inadequate incentives for the proper care and maintenance of rainwater system infrastructure, and for budgeting of water use.
- Lack of awareness and understanding by households about how to properly manage use of water.

Climate change may also contribute to the Lofeagi water scarcity problem in the future through changing rainfall patterns and drought frequencies. The best-available science indicates that future annual and seasonal mean rainfall is most likely to increase (high confidence) and the incidence of drought most likely to decrease (moderate confidence) (PCCSP, 2011). However, these projections are subject to material uncertainties. Less likely but still very possible 'hottest and driest' climate scenarios (using the climate futures tool) indicate that the direction of change could be the reverse of that described for most likely.

Options

The option being constructed/implemented by the Tuvalu PACC project is a community cistern. This cistern is built to utilise the catchment available from a nearby church. It has a storage capacity of 750 m^3.

Costs and benefits

The costs considered in the CBA related to setup (capital) and operation of the community cistern. The costs covered in the CBA included the following:

- Capital
- Materials for roofing, gutting, pump and tank for the community cistern (A$78,596);
- Rental of cement mixer (AUD$336), trucks (AUD$700), dump truck (A$2,400) and loader (A$3,200)[17] needed for construction;
- Fuel (A$720);
- Labour (A$73,196);
- Operation
- Labour (AUD$12.50/year)
- Materials (AUD$78.60/year)

The benefit streams were considered as three main categories.

The first category related to the direct benefits of water supplied from the cistern. This was estimated simply as unit value of water multiplied by the quantity of water supplied.[18] The unit value of water applied was differentiated for portions of water corresponding to: (i) the amount of desalination water that is expected to be purchased under business as usual and would be offset by the cistern (363,680 litres per year increasing in line with population[19] at A$0.022 per litre[20]); (ii) the amount of water that is expected to be purchased as bottled drinking water under business as usual and is expected to be offset by the cistern (1,117 litres per year increasing in line with population at A$0.70 per litre); and (iii) the amount of water that is additional to what is expected to be delivered under business as usual (remaining amount at A$0.005 per litre[21]). The total quantity of water supplied from the community cistern is expected to be 1,460,000 litres per year for an (historical) average rainfall year[22].

The second benefit category related to reduced incidences of water-related sickness and disease. Where community members fully understand the health risks of drinking poor quality or insufficient water and where health services are not significantly subsidised (such that individuals consider the full cost of health services in their decisions to purchase water), the value of water estimated in the first benefit category should capture most of the health-related (indirect) benefits of additional water supply. However, in practice these conditions sometimes do not hold and so some proportion of health benefits from additional water supply should be considered separately. In this study, lack of data/information[23] and time constraints did not allow this benefit category to be quantified. Suffice to say, lower incidence of water-related health problems is considered to be a significant benefit of the community cistern.

Finally, avoided travel costs associated with collecting supplementary desalination water during drought periods were considered. This was calculated as the sum of lost time avoided and avoided transport costs. Avoided time costs from purchasing desalinated water were calculated as the number of deliveries of desalinated water to Lofeagai in an average year (97) multiplied by the estimated amount of time spent on buying desalinated

17 Calculated based on estimated number of days (10), working hours per day (8 working hours) and the rental rate per hour ($40).

18 This approach is justified by the pilot project being a relatively small-scale project and so is not expected to change the level of communities' willingness to pay for water.

19 Population is assumed to increase at the current growth rate of 1.86%.

20 this is the price charged to the Lofeagi community ($0.047/litre) plus the Government subsidy for this water ($0.017/litre). this is expected to increase at 2% per year in real terms.

21 This is the price charged to the Lofeagi community (A$0.047/litre). It does not include the government subsidy for this water (A$0.017/litre).

22 This is calculated through a relatively complex 'if' formula incorporating monthly rainfall, catchment area of church roof, a catchment efficiency factor, storage capacity of cistern, and withdrawals during the months April to October. This spreadsheet is available from Tuvalu Government upon request.

23 Particularly on the causal relationships between inadequate (quantity and quality) water supply and the incidence of health incidences.

water (3/4 of an hour) multiplied by the value of time (approximated as the average wage rate, A$2.50). Avoided transport costs was calculated by multiplying the number of trips (97) by the bus costs per trip (A$0.24) by the proportion of trip spent performing water collection activities (0.25).

Results and sensitivity analysis

Once the costs and benefits of the project options were quantified, the data were used to determine the net benefit of the proposal. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 2.3A below. Note: the NPV results are in year 2012 Australian dollar values and the cistern was assumed to function for 30 years.

TABLE 2.3A. Tuvalu PACC CBA results

	Economic results
	Community cistern
(1) Present value of costs at 8% discount rate	148,978
(2) Present value of benefits at 8% discount rate	
Additional water supply	197,485
Improved health	*Not valued*
Avoided travel costs	2,094
	199,579
(3) NPV = (2) – (1)	50,601
(4) BCR = (2) / (1)	1.34

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Some of the key variables/assumptions tested were: (i) unit value of water for portion of water that is additional to what is expected to be delivered under business as usual (tested effect of assuming willingness to pay for this portion of water is two times the cost of producing desalination water at A$0.0010 per litre as well as the price reported to have been charged by a private business in Tuvalu in 2004 of A$0.030 per litre); (ii) expected future rainfall (assumed future rainfall will be 1 standard deviation below historical average levels, which translates to an annual supply of water from the community cistern of 730,000 litres using the 'if' Excel formula developed); and (iii) discount rate (4% was also tested to be consistent with other PACC CBAs). Results of the sensitivity analysis are given in Table 2.3B.

TABLE 2.3B. Tuvalu PACC CBA sensitivity analysis results

Variables	Primary results		Sensitivity test results	
	NPV ($)	**BCR**	**NPV ($)**	**BCR**
(i) Unit value of water (A$0.0095 per litre and A$0.030 per litre)	50,601	1.34	104,846; 339,501	1.70; 3.28
(ii) Future rainfall (1 standard deviation below historical average)	50,601	1.34	12,813	1.09
(iii) Discount rate (4%)	50,601	1.34	167,644	2.08

Conclusions

The results of the CBA confirm the community cistern at Lofeagi represents a worthwhile project option to be implemented as part of the Tuvalu PACC project.

To help make sure the benefits of the PACC pilot project are realised, it is important that a cistern management plan be developed with responsibility for monitoring assigned to a community body. The technical assistance of a water specialist and the Met Office should be sought to help develop this plan. The cistern management plan will need to include suggested extraction schedules based on different rainfall scenarios and simple, user-friendly triggers for community members to manage this appropriately. It should also include a maintenance schedule. The PACC project should assist the Lofeagi community in developing this management and monitoring plan and conduct training and awareness with community members on the plan.

More generally, given the apparent benefits of reducing dependency on desalinated water over the longer term, there would be merit in examining in more detail water demands and the water pricing structure (for desalination water) in Tuvalu in order to strengthen the incentives for water conservation whilst ensuring that basic needs are met. This could involve for example a progressive pricing structure that keeps the current pricing structure for purchases up to a certain quantity of desalinated water but gradually increases them for water purchases above that quantity.

Before decisions are made about up-scaling and replicating the community cistern pilot, it would be prudent to wait and see how this project actually performs in reality. Monitoring of the pilot project should include collection of rainfall data, water harvest/storage by cistern, and water use (detailing quantity, timing, and who uses the water). This actual/observed data can then be used to repeat this CBA exercise. This 'ex-post' CBA should be a key part of pilot evaluation, which can then be used to reliably inform decisions about up-scaling and replication.

Success factors, key challenges and outcomes of CBA implementation

SUCCESS FACTOR 1 – A success factor of the Tuvalu PACC CBA was there was very active engagement from economists from the Tuvalu Ministry of Finance and Economic Development, who in fact led on the quantitative analysis and report writing. This resulted in a high level of understanding and ownership of the CBA, which is considered to be a key reason why recommendations of the CBA report have been accepted.

SUCCESS FACTOR 2 – Another success factor was the arrangement for providing technical backstopping for this CBA. This support was provided intermittently over a period of 6 months by an economist with significant experience in the Pacific region and Tuvalu specifically. This arrangement allowed sufficient time for Tuvalu government officials to conduct the CBA alongside their other work tasks.

CHALLENGE 1 – One drawback was the late introduction of the CBA. The CBA would have been more useful for the PACC project if it was undertaken prior to implementation and could have examined a number of different options.

OUTCOME 1 – The Tuvalu PACC team have taken on board the advice of the CBA to implement a cistern management plan in order to fully realise the potential benefits of the project.

PART 3 AGRICULTURE CBA SUMMARIES

CBAs were conducted for two food security PACC pilot projects in Palau and in Solomon Islands.

The Palau CBA was undertaken mid way through project implementation. The objectives of this CBA were to inform possible project design refinements for the remainder of the PACC pilot; and to help set up a more robust monitoring and evaluation framework to provide for quantitative evaluation at the end of the project, through an ex-post CBA.

The Solomon Islands CBA was undertaken prior to project implementation. The objective of this CBA was to inform selection and design of pilot measures to be progressed under the PACC.

The summaries for these CBAs below differ slightly to the full CBA reports completed. The reason for this is mostly to simplify the CBA summaries for the purposes of learning. The author takes full responsibility for differences in results and recommendations presented below.

3.1. Palau

Problem statement

Palau is facing increasing stress across all dimensions of food security including adequacy (being able to grown your own food), access (having income to buy food), utilisation (knowledge of nutrition, storage and preservation), and safety (Palau National Committee on Population and Children, 2011).

Food imports in Palau have grown by 133% in the last decade, while the population has increased by 20% (Ryan, 2008). In 2010, the total value of food imports (primarily low-nutrition processed food and rice) was US$24.5 million, which represents over 10% of GDP. Further, the 2006 Household Income and Expenditure Survey (HIES) shows imported food constitutes between 81% and 84% of total food consumption – making Palau one of the least food secure of the Pacific island countries.

Food insecurity (and related obesity), along with tobacco, are the most significant factors affecting the health of Paluans (Palau National Committee on Population and Children, 2001). Incidence of non-communicable diseases (NCDs) and diabetes in particular has increased in the past decades (draft Palau National Plan for Action in Nutrition, 1999), and the scale of the problem has now reached such a level that has prompted President Toribion, in 2011, to declare a 'state of emergency' in relation to the rising cases of NCDs in Palau.

One component of the adequacy dimension of the Palau food security problem is declining taro production. Taro has historically been a main agriculture crop in Palau and is used largely for subsistence. Unfortunately, there are no recent or reliable estimates of Palau's taro production. Data obtained from Palau's largest taro and root crop buyer indicate taro production is declining at roughly 3.5% per year (data supplied by Yano and Sons to the Palau PACC CBA team for the period 2002 to 2012).

Causes and drivers of declining taro production

One driver of declining taro production is saltwater incursion into taro plots associated with extreme sea level/high tide events. When salt water incursion events occur, this degrades soil quality and thus reduces yields.

Over the period 1969 to 2009, extreme tide events which result in significant saltwater incursion have occurred once every five years on average (PCCSP, 2011). The PCCSP (2011) projects with 'very high confidence' that sea level near Palau will increase by between 5 and 15 cm by 2030 under medium and high emission scenarios. This in turn is expected to contribute to increased frequency and extent of inundation events.

Other causes or drivers of declining taro production were not considered in detail in this CBA.

Options

One option that is being trialled as part of the PACC project is a taro adaptation project. This option comprises two parts as follows:

- Trialling of 19 different local and introduced taro varieties (13 popular and widely grown Palauan varieties and six introduced hybrids from the SPC-CePaCT germplasm collection[24]) to evaluate resistance to saline conditions; and
- Trialling of improved taro plot engineering to prevent saltwater intrusion. This includes enhancing earth dikes, repairing internal channels and installing simple flood and water flow gates.

The pilot started implementation in November 2011. The pilot is located at the Ngimis Village taro patch in Koror, which is situated close to mangrove swamp where the likelihood of saltwater intrusion is high. The area of the taro patch is 585 m^2. The taro pilot is being implemented in collaboration with the Cooperative Research and Extension (CRE) Department of the Palau Community College (PCC).

Costs and benefits

The costs considered in the CBA related to setup of the taro plot and included building dikes and gates, and acquiring salt-tolerant planting material. The costs covered in the CBA are the costs that farmers would incur to replicate the Ngimis pilot (US$4,300).

Operating costs such as planting, maintenance, fertiliser and harvesting (US$1,600 per year) are not treated as an additional cost in this analysis because these costs are considered to be approximately the same as for taro production using standard taro farming techniques. Note also that no material environmental impacts are expected from the new taro farming approach, though further investigations are required to confirm this. This will be done as part of the monitoring and evaluation for the PACC pilot project.

The benefit streams were considered as four separate categories.

The first benefit category related to the avoided production losses that would be incurred if the package had not been adopted. This was calculated by estimating the quantity of taro production saved from the adaptation measures relative to no adaptation measures being implemented over a 25 year[25] period, and then multiplying this by the market price of taro (US$5.50/kg). Without the adaptation measures, taro production is expected to be impacted by extreme tide events in the same way as was experienced in a 1998 extreme sea-level rise event which resulted in no taro production the following year and 50% of normal production for two years after the event (Damage Assessment Report, National Emergency Office, 1998). With the adaptation measures, taro production is expected to be approximately 1090 kg per 585 m^2 patch, consistent with the results from the Ngimis trial so far. For the central analysis, an extreme high tide is assumed to occur once every five years in line with the historical average for Palau over the period 1969 to 2009 (PCCSP, 2011).

The second benefit category considered was health benefits from substituting taro for imported grain.[26] The nutritional and thus health consequences of substituting rice and other imported grains for traditional taro are well documented (Otto, 2000). Healthier individuals are more productive, live longer and spend less on health care. The overall productivity of the work force is increased and public expenditure on health care is reduced. In principle, the health benefits from reversing, or at least reducing, the observed trend of substituting imported grains for taro can be quantified (e.g. through avoided health costs and avoided lost income), however, due to limited time and resources this quantification is beyond the scope of this study. Suffice to say that these benefits are important.

24 The varieties planted at the Ngimispilot were – Local varieties: Ochelochel, Kirang, Ungil Dil, Okelang, Dungersuul, Ngesuas, Homusted, Dirrubong, Prak, Terrekakl, Kerdeu, Ochab, Dirratengadik; and introduced varieties: TAN/IND 14, TAN/MAL 14, BL/HW 12, BL/SM 10, BL/SM 12, BL/SM 111.

25 This is considered to be a conservative estimation of the expected useful life of earth dikes. A substantial, well-built traditional earth dike can be expected to last four or five generations.

26 It should be noted that, because Palaun's do not have good knowledge about the health benefits of taro relative to rice and because hospital and medical costs in Palau are subsidised, the market price for taro is unlikely to reflect the full economic value of taro production. As such, health benefits can be considered as a separate benefit category.

The third benefit category was foreign exchange savings for Palau. This was calculated by multiplying the quantity of rice imports that are expected to be offset from additional taro production associated with the adaptation measures by the market price of rice at Palau (US$1.30/kg). The quantity of rice imports expected to be offset was roughly approximated using calorific equivalent data of taro to rice. Approximately 2.9 kgs of taro are required to produce the calorie equivalent of 1 kg of white rice (SPC, nutritional tables).

Finally, the cultural benefits from maintaining taro patches were considered. The taro patch has historically played a key role in the culture and traditions of the Palauan people and thus the maintenance of wetland taro production brings with it cultural benefits. However, as important as these benefits are, it is very difficult to try and assign a dollar value to them. This is beyond the scope and resources of this study. Suffice to say that these are important.

Results and sensitivity analysis

Once costs and benefits of the project options were quantified, the data were used to calculate the net benefit of the pilot project. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 3.1A below. Note the NPV results are in expressed in 2012 US dollar values. Note also that a column has been included to show the financial results for farmers in particular. This is included to show the private financial feasibility of the adaptation measures.

TABLE 3.1A. Palau PACC CBA results

	Financial results (to farmers only)	Economic results (whole of society)
(1) Present value of costs at 4% discount rate	$4,135	$4,135
Capital investment costs	$4,135	$4,135
(2) Present value of benefits at 4% discount rate		
Avoided loss of taro production from extreme tide events	29,895	29,895
Improved public health from substituting rice with taro	*n/a*	*Not valued*
Foreign exchange savings	*n/a*	2,437
Cultural benefits of maintaining taro plots	*n/a*	*Not valued*
	29,895	32,331
(3) NPV = (2) – (1)	25,595	28,031
(4) BCR = (2) / (1)	6.95	7.52

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the discount rate (a 10% discount rate was applied as this is perhaps a rate more appropriate for a private investor/farmer who has a shorter time horizon); (ii) the effectiveness of the adaptation measures in mitigating production losses (a reduction in effectiveness from 100% to 50% was modelled); and (iii) the frequency of extreme high tide events (sensitivities modelled include extreme high tide events occurring 1 in every 4 years and 1 in every 3 years as could potentially occur under the effects of climate change).

The sensitivity analysis results are presented in Table 3.1B below.

TABLE 3.1B. Palau PACC CBA sensitivity analysis results

Variables	Primary results		Sensitivity test results	
	Financial	Economic	Financial	Economic
(i) 10% discount rate	25,595 (6.95)	28,031 (7.52)	13,824 (4.21)	15,301 (4.56)
(ii) Effectiveness of measures in mitigating production losses is 50%	25,595 (6.95)	28,031 (7.52)	10,647 (3.48)	27,059 (7.29)
(iii) Frequency of extreme high tide event is 1 in 4 years	25,595 (6.95)	28,031 (7.52)	33,069 (8.69)	36,114 (9.40)
(iv) Frequency of extreme high tide event is 1 in 3 years	25,595 (6.95)	28,031 (7.52)	45,525 (11.59)	49,586 (12.53)

Conclusions

The results of the CBA indicate that improved taro plot engineering and more salt-resistant taro varieties – as currently being piloted in the Palau PACC project – will likely generate net financial benefits for farmers. That is, the additional revenues of implementation outweigh the increased expenses of setting up the new production system such that it is profitable (or financially feasible) for the private sector (farmers) to implement/replicate by themselves. This result holds true for discount rates of both 4% and 10%, assumptions about the effectiveness of adaptation measures in mitigating production losses from saltwater inundation (both 100% and 50%), as well as different future climate scenarios for high tide events.

From a whole-of-society perspective the results also indicate that the piloted adaptation measures appear to represent a worthwhile use of resources, generating health benefits, foreign exchange savings, and cultural benefits on top of the net financial gains to farmers. As such, the PACC taro pilot measures look promising for potential up-scaling and replication, noting that it may not be appropriate for further government intervention in these activities beyond demonstration.

Before information is disseminated to farmers and any replication or up-scaling occurs, it is recommended that the PACC taro pilot project be expanded to two other sites in Koror and Ngaraard states. It is the opinion of the CBA consultant (Andrew McGregor) that a larger sample size is required to generate the data needed for meaningful and reliable analysis.

It is further recommended that monitoring and evaluation activities include collection of information on the benefits and costs not quantified in this CBA (particularly cultural benefits and any negative environmental impacts). This CBA exercise should then be repeated at the end of the trial/pilot to generate knowledge products for farmers and government. Finally, end-of-project evaluation should also assess the nature and extent of other barriers or constraints that may affect the uptake of the piloted adaptation measures by farmers. This will inform what other government interventions and/or assistance is warranted for any up-scaling and replication activities.

Success factors, key challenges and outcomes of CBA implementation

SUCCESS FACTOR 1 – A success factor of the Palau PACC CBA was that there was very strong engagement by agronomists involved in the pilot project. This provided for greater understanding and ownership of the CBA results and findings, which in turn has contributed to uptake of the CBA recommendations.

SUCCESS FACTOR 2 – Another success factor was the agricultural knowledge and the extensive Pacific experience of the economic consultant engaged to help conduct the CBA. Among other things, this helped facilitate engagement of the country agronomists in the CBA exercise.

CHALLENGE 1 – A difficulty experienced was that project management personnel for the Palau PACC changed in the time between CBA workplans were prepared and the consultant arrived in-country to help conduct the CBA. This meant that persons involved in the work planning of the CBA did not oversee or participate in the conduct of the CBA. This has likely resulted in fewer Palau government officials understanding the CBA which in turn may reduce the likelihood that some of the recommendations will be taken up.

OUTCOME 1 – The Palau PACC team have taken on board the advice of the CBA to expand the taro pilot in order to generate more reliable and meaningful results.

3.2. Solomon Islands

Problem statement

The low-lying outer atolls of Ontong Java, Solomon Islands are facing increasing food security stresses (PACC Vulnerability and Adaptation (V&A) Assessment Report, 2011; Jansen et al., 2006). This is leading to worsening health outcomes for the Ontong Java community, such as increasing incidences of high blood pressure, diabetes, diarrhoea, TB, and yaws (Solomon Islands National Statistics Office, 2006).

Key elements of the food security problem on Ontong Java are:

- Declining production of subsistence foods, particularly giant swamp taro (*Cyrtosperma merkusii)* and 'taro tru' (*Colocasia esculenta)*. The extent of reduced production is not precisely known as no quantitative surveys of food production on Ontong Java have been undertaken since 1986. However, community consultations undertaken as part of the PACC project indicate that it is substantial and is expected to continue to decline into the future.
- Increasing population. Since 1986 the population on Ontong Java has approximately doubled and at 2009 stood at 2,857 people (2009 census). With a land area of only 12 square kilometers, the atoll now has a population density of around 250 persons/km^2.
- Sharp declines in household incomes. In 2011 the Government imposed a ban on the trade of beche-de-mer, which hitherto accounted for around 95% of total income for Ontong Java households.

As at 2011, 63% of available income on Ontong Java was reported to be spent on the purchase of imported food (Solomon Islands National Statistics Office, 2006).

Causes and drivers of declining taro production

One driver of declining subsistence food production, including taro production, is saltwater incursion into garden plots from extreme sea level/high tide events. When saltwater incursion events occur, this degrades soil quality and thus reduces yields.

According to the Ontong Java communities' observations, the incidence and extent of saltwater intrusion has increased in recent years. The community reported that garden plot contamination now occurs at locations where it has never been experienced in the past (PACC V&A Assessment Report, 2011).

The PCCSP also reports that the sea level rise near the Solomon Islands is increasing by over 8 mm per year (ABM and CSIRO, 2011). Saltwater inundation is expected to be further exacerbated in the future from El Niño southern oscillation (ENSO)-induced tidal fluctuations and increasing (albeit gradual) average sea level under climate change.

Other causes and drivers of declining taro production identified as part of the PACC project include loss of traditional knowledge about land and farming practices[27], and disease.

27 The elders related that loss of soil fertility was due to loss of traditional knowledge by the younger generations. This reflects a long history of poor land use practice, which is related to over and unsustainable use of available land and in some instances use of inorganic fertilizers to boost agricultural production (PACC V&A Report, 2011).

Options

Three broad project options were identified as part of the PACC project for improving food production on Ontong Java.[28] These are:

- Taking measures to reduce saltwater contamination in food production areas;
- Introducing root crop varieties and cultivars that have tolerance to salinity; and
- Modifying the soil and food production environment.

Only option 3 was assessed as part of this CBA. This was in part due to resource constraints to conduct the CBA. Option 3 was judged by the CBA consultant and three root crop experts in the Pacific region[29] to be the option with the highest probability of success in the timeframe of the PACC project.

Option 3 builds on the current Anglican Church of Melanesia (ACM) food security and water supply project. It involves an integrated combination of the following measures:

- Improved composting techniques that increase the volume and quality of available compost;
- Agroforestry techniques that involve the use of nitrogen fixing trees and legumes;
- Growing vegetables in raised beds and containers (including appropriate hydroponics) and improved home gardening techniques;
- The establishment of small nurseries for high quality vegetable seedlings and agroforestry planting material; and
- The introduction of the 'soils school' extension methodology so people understand their soil and how best to utilise it for sustainable food production.

Costs and benefits

The costs considered in the CBA related to collection of baseline information, capital construction costs, and operational activities as well as a 15% contingency provision. These activities are many and varied and are detailed in Annex 1 of the full CBA report (available from Solomon Islands PACC upon request). Total project costs over a three year period are estimated at SBD$2.5 million (US$350,000).

The benefit streams were considered as three separate categories.

The first benefit category related to the additional taro production that would be generated from the package of measures outlined under option 3. Taro production was taken to be a proxy for all types of food crop that could be grown as part of the pilot measures. The quantity of additional taro produced was calculated as the quantity of taro produced with the project (assumed to increase to 1986 levels[30] in five years, where it remains for the next decade) minus the quantity produced without the project (assumed to decline to 50% and 0% of 1986 levels by 2025 for swamp taro and 'taro tru', respectively[31]). In the absence of market information for taro on Ontong Java (taro is grown on Ontong Java for subsistence use only), the unit value of taro was approximated as the value of the equivalent amount of rice measured in calorific terms. Calorific equivalency ratios were derived from 2006 SPC nutrition tables (1 kg rice is equivalent to approximately 2.41 kg swamp taro and 0.98 kg 'taro tru'). The market price of rice on Ontong Java in 2012 was about SBD$14/kg.

28 The CBA report prepared for the Solomon Islands PACC pilot project concluded that a pilot project for Ontong Java could be designed for any of the pillars of food security: adequacy (being able to grow your own food), access (having income to buy food), utilisation (knowledge of nutrition, storage and preservation) and safety. The decision to focus on households being able to grow their own food is based on the PACC V&A Report which concluded that the best prospects for enhancing food security on Ontong Java in the short to medium term lie with improving domestic food production.

29 The experts were: Dr Vincent Lebot, of CIRAD, based in Vanuatu; Dr Mary Taylor, until recently Genetic Resources Coordinator and Manager of the SPC's Pacific's regional genebank, the Centre for Pacific Crops and Trees; and Dr Grahame Jackson, root crop pathologist and long-standing authority on Solomon Island agriculture.

30 The last detailed study of cropping systems and food production on Ontong Java was conducted in 1986 by Bayliss-Smith as part of the AusAID South Pacific Small Holder Project. This study reported that production of 'taro tru' and swamp taro in 1986 was 25 tonnes and 73 tonnes respectively.

31 This is a crude judgement made by the CBA consultant in the absence of any reliable data since 1986. The much higher rate of decline assumed for 'taro tru' production is in part due to this varieties' much lower salinity tolerance than swamp taro.

The second benefit category considered was health benefits from substituting taro for imported grain.[32] The nutritional and health consequences of substituting rice and other imported grains for traditional taro are well documented (Otto, 2000). Healthier individuals are more productive, live longer and spend less on health care. In principle, the health benefits from replacing imported grains with taro can be quantified (e.g. through avoided health costs and avoided lost income), however, due to limited time and resources this is beyond the scope of this study. Suffice to say that these benefits are important.

The final benefit category considered is avoided costs associated with out-migration. The Solomon Islands are already dealing with unsustainably high rates of urban migration with the attendant environmental and social problems of poverty, squatter housing, over-taxed infrastructure, congestion, pollution crime and political instability. Worsening food insecurity will increase the pressure on people to migrate to Honiara and associated problems. To the extent the proposed project reduces the rate of out-migration through improved food security it represents a project benefit. While such benefit are expected to be substantial, it is beyond the scope of this CBA.

Results and sensitivity analysis

Once costs and benefits of the project options were quantified, the data were used to calculate the net benefit of the pilot project. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 3.2A below. Note the NPV results are in expressed in 2012 Solomon Islands dollar values.

TABLE 3.2A. Solomon Islands PACC CBA results

	Economic results (whole of society)
(1) Present value of costs at 4% discount rate	
Baseline, capital investment, and operational costs	2,637,792
	2,637,792
(2) Present value of benefits at 4% discount rate	
Increased taro production	*Not valued*
Improved public health from substituting rice with taro	*Not valued*
Benefits associated with reduced out-migration to Honiara	6,359,840
	6,359,840
(3) NPV = (2) – (1)	3,722,049
(4) BCR = (2) ÷ (1)	2.4

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the rate of taro decline for the without-PACC intervention scenario (an alternative was modelled where it is assumed current production is 10% and 50% below 1986 levels for swamp taro and 'taro tru' respectively, and production will remain constant at this level for the next 13 years); and (ii) the effectiveness of the adaptation measures in increasing taro production. Three alternative scenarios were modelled to test the effectiveness of the adaptation measures in increasing taro production parameter, in part to reflect uncertainties related to future extreme tide hazards under climate change. These were:

- Taro production is restored to the 1986 level in three years and then gradually increases for the next decade (seen by the consultant as possible but unlikely);
- Taro production is restored to the 1986 level in three years, where it remains for the next decade (seen by the consultant as challenging but possible); and

32 It should be noted that, because Ontong Java community members do not have good knowledge about the health benefits of taro relative to rice and because hospital and medical costs in Solomon Islands are subsidised, the market price of calorific equivalent quantities of rice is unlikely to reflect the full economic value of taro production. As such, health benefits can be considered as a separate benefit category.

- Taro production is restored to 50% of the 1986 level in three years, where it remains the same for next decade (seen by the consultant as a disappointing result if the project could not achieve at least this level of outcome).

The sensitivity analysis results are presented in Table 3.2B below.

TABLE 3.2B. Solomon Islands PACC CBA sensitivity analysis results

Variables	Primary results		Sensitivity test results	
	NPV ($)	BCR	NPV ($)	BCR
(i) Taro production without PACC intervention (taro production remains constant at 90% and 50% of 1986 levels for swamp taro and 'taro tru' respectively)	3,722,049	2.4	1,836,527	1.7
(ii.a) Effectiveness of PACC intervention in increasing taro production (taro production is restored to the 1986 level in three years and then gradually increases for the next decade)	3,722,049	2.4	5,424,761	3.1
(ii.b) Effectiveness of PACC intervention in increasing taro production (taro production is restored to the 1986 level in three years, where it remains for the next decade)	3,722,049	2.4	4,217,759	2.6
(ii.c) Effectiveness of PACC intervention in increasing taro production (taro production is restored to 50% of the 1986 level in three years, where it remains the same for next decade)	3,722,049	2.4	1,732,689	1.7

Conclusions

The results of the CBA indicate that the proposed package of measures to improve the soil and food production environment on Ontong Java will likely generate net benefits for the Ontong Java community. As such, it is recommended that these measures be progressed as part of the Solomon Islands PACC project.

To ensure the Solomon Islands PACC pilot project is able to develop robust and reliable evaluation information at the end of the project, baseline information on soil fertility and salinity should be collected before the commencement of the pilot project. A robust and empirical evaluation of the measures implemented under the Solomon Islands PACC project is needed to adequately inform decisions about up-scaling and replication in other Solomon Island atoll areas as well as other PICTs.

Success factors, key challenges and outcomes of CBA implementation

SUCCESS FACTOR 1 – A success factor of the Solomon Islands PACC CBA was the agricultural knowledge and the extensive Pacific experience of the economic consultant engaged to help conduct the CBA. Among other things, this helped to fill gaps in the Solomon Islands PACC (CBA) team relating to technical agronomist inputs.

SUCCESS FACTOR 2 – Another success factor was the completion of a good-quality vulnerability and adaptation assessment prior to the start of the CBA. Information in this assessment provided very useful inputs to the CBA and helped to complete the CBA in a timely and efficient manner.

CHALLENGE 1 – A difficulty experienced for the Solomon Islands PACC CBA was that technical officials from the Solomon Islands Government (agronomists, meteorologists, etc.) did not actively participate in the planning or conduct of the analysis. This resulted in low understanding of the quantitative elements of the CBA which in turn may lead to some of the recommendations relating to implementation (e.g. collection of baseline data) not being followed.

OUTCOME 1 – The Solomon Islands PACC team have taken on board the advice of the CBA to focus on the package of measures to modify the soil and food production environment on Ontong Java. Costing information collated as part of this CBA has been especially useful in determining what activities are feasible within the available Solomon Islands PACC budget.

PART 4 COASTAL INFRASTRUCTURE CBA SUMMARIES

CBAs were conducted for two coastal infrastructure PACC pilot projects in the Cook Islands and Samoa.

The Cook Islands CBA was undertaken prior to project implementation. The primary objective of this CBA was to inform whether the suggested pilot project should be progressed.

The Samoa CBA on the other hand was undertaken two years after the infrastructure had been constructed. The objective of this CBA was to help inform whether this project was successful and thus is worthwhile replicating in other parts of Samoa (and the broader Pacific region).

4.1. Cook Islands

Problem statement

The Mangaia-Avarua Harbour is key infrastructure for Mangaia Island, which is in the Southern Group of the Cook Islands. It is the only harbour on the island and is thus a core part of the transport links that help provide affordable access to markets in Rarotonga and beyond. It is also the primary point of safe ocean access for Mangaia fisherman, who are the main providers of fish and protein for Mangaia Islanders.

The current harbour is considered to be vulnerable to damage from relatively low intensity cyclone events due to its poor design as well as incomplete construction. The wave force strength of the current harbour is not precisely known but is estimated to be roughly commensurate with a 1 in 35 year cyclone event (Tenga Mana, personal communication, June 2012).

Also, the current harbour design is considered to be unsafe to use for a substantial period of the year, when winds are greater than 10 knots (Tenga Mana and Josh Taio, personal communication, June 2012). Wind conditions greater than 10 knots are estimated to currently 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)[33]. When unsafe conditions occur, Taio Shipping does not operate its cargo service to Mangaia, which in turn causes delays and related losses (Josh Taio, personal communication, June 2012). Also, local fisherman do not generally use the harbour during these times either, with some fisherman instead travelling to an alternative ocean access spot on the other side of the Island). To date, there have no reported injuries or deaths associated with use of the harbour under rough sea conditions although there have been some reported 'close calls'. The Mangaia community view safety risks as a significant problem with the current harbour .

In the longer term, sea level rise also presents a risk to the Mangaia-Avarua Harbour as the quay platform is likely to become submersed and rock walls less effective at blocking wave action. However, adaptation measures[34] for sea-level rise in this context (i.e. retrofitting an already existing harbour) are considered to be most efficiently undertaken at the time when sea-level rise starts to create operational problems (Richard Frankland BECA engineering and related consultancy services, personal communication, May 2012). As such, risks associated with sea-level rise are not considered further in this summary.

33 Future projections for wind direction and speed (and hence rough seas) are uncertain. If El Niño becomes more prevalent in the Pacific region under climate change then the frequency of these conditions would increase. However the extent of this increase is expected to be small over the next 50 years – approximately one additional day per month during cyclone months (Maara Vaiimene, personal communication, August 2012). The opposite is true if La Niña becomes more prevalent.

34 An example is raising the height of the quay platform.

Options

The measures proposed for this demonstration are:

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

- Extend the width of the concrete hardstand to reduce degradation of hardstand;
- 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)
- Complete the channel widening and deepening works to minimise wave setups in the channel;
- Relocate the boat ramp to the south of the quay platform to minimise ramp exposure to waves entering the channel;
- Construct a beach spending zone to the north of the existing boat ramp to dissipate any wave energy and hence minimise turbulence.

Costs and benefits

The costs considered in the CBA related to the capital construction costs of each of the retrofit measures as well as environmental impacts.

The capital construction costs considered in the CBA were the following (Mana and Maoate, 2012):

- Extending the width of the concrete hardstand (NZ$285,599);
- Installing precast concrete panels along the face of the quay walls (NZ$145,430);
- Completing the channel widening and deepening works (NZ$199,418);
- Relocating the boat ramp to the south of the quay platform (NZ$64,260);
- Constructing a beach spending zone to the north of the existing boat ramp (NZ$6,514).

Environmental impacts mostly relate to the extension or widening of the channels and basins of the harbour and are within the vicinity of the existing harbour. These environmental costs were not valued because these impacts are not considered to be significant (OMIAMW, 2007), and because it would require significant time and resources to accurately do this analysis.

The benefit streams were considered as five separate categories.

The first category related to the benefits from avoided cyclone damages to the harbour from cyclone events. This was calculated using the replacement cost method whereby damages are approximated using the capital cost of the existing infrastructure (which is NZ$1,550,000[35]). This calculation assumed that in the event that a cyclone occurs which exceeds the (design) threshold of the harbour, then the harbour will be completely destroyed (Richard Frankland BECA, personal communication, May 2012), requiring full replacement. The proposed retrofit measures were assumed to strengthen the resilience of the harbour to wave forces due to cyclone, from approximately a 1 in 35 return period cyclone (without the project) to a 1 in 50 year cyclone event (Tenga Mana, personal communication, June 2012). The total value of damages avoided from harbour strengthening is therefore estimated as the difference between the expected value of damages with the project and the expected value of damages without the project.[36]

35 Letter of acceptance contract NZ$1.75m less $200k unspent.

36 The calculation is (1/35 – 1/50) x (replacement cost). This is done every year for 20 years. 20 years is the duration of this benefit stream because without the retrofit measures (i.e. without the project), it is assumed that new wharf infrastructure will be constructed after 20 years which will have similar cyclone force thresholds to the retrofit design.

The second benefit category related to 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. The value of this deferred investment is approximated as investment expenditures in a new harbour without the project (i.e. business as usual) minus investment expenditures in a new harbour with the project over 50 years, and applying a discount rate of 4% to account for the opportunity cost of capital over this period. The capital cost of a new harbour is taken to be NZ$2,401,630 (GHD Design report, 2006). The retrofit measures proposed are assumed to extend the useful life of the harbour infrastructure to 50 years, from 15 years under the without-project scenario (Tenga Mana, personal communication, June 2012).

The third benefit category considered was the losses to Taio Shipping avoided associated with improved (safe) access to the Mangaia harbour. The value of avoided losses for Taio Shipping was calculated as the number of delay days avoided from the retrofit harbour relative to the current design (1.97 days per year) multiplied by the cost per day of running and manning the vessel (approximated at NZ$10,000 per day; Josh Taio, personal communication, June 2012)[37].

The fourth benefit category considered was losses to fisherman avoided associated with increased (safe) access to the Mangaia harbour. The value of travel costs avoided from improved operational design of the harbour was calculated as the time saved by a fisherman launching his vessels (30 hours per year[38]), multiplied by the number of fishing vessels that regularly operate (10; figure supplied by Poroa Arokapiti, local fishermen and Secretary of the Fishing Club), multiplied by the value of time, which in this case is approximated as the minimum wage for the Cook Islands (NZ$4 per hour).

Finally, the benefits from reduced potential for injury or death whilst using the harbour were considered. Data on current and future risks of injury or death from using the Mangaia harbour are not readily available. For this reason the benefits of reduced potential for injury or death are not valuated in monetary terms in this analysis.

Results and sensitivity analysis

Once the costs and benefits of the project options were quantified, the data were used to determine the net benefit of the proposal. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 4.1A on the following page. Note: the NPV results are in year 2012 New Zealand dollar values.

37 More accurate estimations of this cost could not be obtained for reasons of commercial confidentiality. Note further, Taio Shipping advise the relevant cargo vessel must still be operated and manned when rough sea conditions make the harbour unsafe, and there is no alternative route or activity the vessel and personnel can be used for during this time.

38 This is calculated as the number of additional days the harbour can be safely used relative to the current design (30 days) multiplied by the additional time taken to launch at the alternate site (1 hour).

TABLE 4.1A. Cook Islands PACC CBA results

	Economic results	
	Measures to improve strength and durability of wharf	Measures to improve safe access to wharf during rough sea days
(1) Present value of costs at 4% discount rate		
Capital construction costs	*$414,451*	*$270,192*
Environmental impacts	*Not valued*	*Not valued*
	$414,451	$270,192
(2) Present value of benefits at 4% discount rate		
Avoided damage from cyclones	*$187,779*	
Deferred investment in new harbour	*$800,875*	
Avoided losses to Taio Shipping		*$273,230*
Avoided losses to fishermen		*$16,622*
Avoided injury or death		*Not valued*
	$988,654	$289,852
(3) NPV = (2) - (1)	$574,203	$19,660
(4) BCR = (2) / (1)	2.39	1.07

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the frequency and intensity of cyclone hazards under future climate change scenarios, which were modelled through changing the return period of the threshold cyclone events that damage the harbour[39]; (ii) the cyclone/storm surge force threshold of the current harbour design, which again was modelled by changing the return period of the threshold cyclone events that damage the harbour[40]; (iii) the durability of the retrofit harbour if not properly maintained (modelled as a reduction in expected useful life from 50 years to 25 years[41]); (iv) combination of ii and iii; and (v) the frequency of windy days which make it unsafe to use the harbour (modelled as ± 6 days per year for winds greater than both 10 knots and 15 knots).[42]

The sensitivity analysis results are presented in Table 4.1B on the following page.

39 For the less frequent future scenario, the 1 in 35 year cyclone event is increased to 1 in 38 years and the 1 in 50 year event is increased to 1 in 53 years. For the more frequent cyclone future scenario, the 1 in 35 year is reduced to 1 in 32 years and the 1 in 50 year event is reduced to 1 in 47 years. These numbers are roughly based on cyclone projection information outlined in the PCCSP Country Report (volume 2) for Cook Islands.

40 For the scenario where wave force strength is lower than estimated, the sensitivity analysis models this as a 1 in 25 year cyclone event threshold. For the scenario where wave force strength is higher than estimated, the sensitivity analysis models this as a 1 in 45 year cyclone event threshold – just below the retrofit design. These numbers are expert judgements by Tenga Mana (engineer, MOIP) of the likely lower and upper bound ranges for this parameter.

41 These numbers are expert judgements by Tenga Mana (engineer, MOIP) of the likely lower and upper bound ranges for this parameter.

42 Upper and lower bound estimates for this parameter could not be generated using the PCCSP climate futures tools. Therefore these estimates are judgements made by Maara Vaiimene from the Cook Islands Met Dpartment and based on available data.

TABLE 4.1B. Cook Islands PACC CBA sensitivity analysis results

Assumptions	Primary results		Sensitivity test results			
			Lower bound		Upper bound	
	NPV (NZ$)	BCR	NPV (NZ$)	BCR	NPV (NZ$)	BCR
Retrofit measures to strengthen harbour to cyclone and extend useful life						
i. Cyclone frequency	$574,203	2.39	$549,589	2.33	$604,917	2.46
ii. Wave force threshold of the current harbour	$574,203	2.39	$824,576	2.99	$435,108	2.05
iii. Durability of retrofit harbour	$574,203	**2.39**	**–$162**	1.00	n/a	n/a
iv. Combined sensitivity ii and iii.	$574,203	**2.39**	**–$139,258**	0.66	n/a	n/a
Retrofit measures to improve access and safe use of harbour during rough sea conditions						
v. Wind frequency	$19,660	**1.07**	**–$38,311**	0.86	$77,630	1.29

Conclusions

Retrofit measures to strengthen the Mangaia harbour to cyclone and improve durability to general weather conditions

The results indicate that retrofit measures to strengthen the Mangaia harbour to cyclone and improve durability to general weather conditions may be worthwhile for implementation under PACC – the central NPV estimate for this option is NZ$354,322. However this result is 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.

As such, it would be prudent to first conduct 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 highlight the importance of developing and implementing a proper maintenance programme for the harbour – otherwise project benefits will not be fully realised. Regular (annual or otherwise) inspection of the structure will permit early detection allowing the implementation of economic maintenance measures. To provide for a maintenance programme (as well as eventual infrastructure replacement), a plan to sustainably finance the harbour should also be developed. Part of this financing plan should include a review of user fees/tariffs.

It should also be 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. Accordingly, knowledge products and communication materials for the Cook Islands PACC pilot project should make this point very clear in order to avoid wasting resources.

Retrofit measures to improve access and safe use of harbour during rough sea conditions

Results for retrofit measures to improve access to and safe use of the harbour during rough sea conditions indicate this project would likely generate a small net benefit for society. While sensitivity results show that retrofit measures could generate a net loss for society if the frequency and intensity of winds from the north and west direction in fact decrease under climate change, the quantitative elements of the CBA did not incorporate benefits of improved safety (i.e. reduced potential for injury and death). Safety is a key element of these measures and safety-associated benefits are considered to be substantial. When these benefits are taken into consideration, it seems likely the proposed retrofit measures will generate a positive net benefit for society and be worthwhile progressing.

To make sure safety benefits are fully realised, it would be wise to also implement a community awareness programme on the proper use of the facilities as a complementary measure.

Success factors, key challenges and outcomes of CBA implementation

CHALLENGE 1 – A difficulty experienced for conducting the Cook Islands PACC CBA was that there was significant pressure (on Cook Islands PACC project team) to start implementing the pilot project (because the Cook Islands PACC CBA was introduced late in the project planning cycle). This meant there was little time available to conduct the analysis or to undertake further engineering analysis as recommended in the CBA.

CHALLENGE 2 – Another difficulty experienced was that some key members of the Cook Islands PACC CBA team were not actively engaged in the conduct of the CBA. This was because (i) the key (technical) government official at Cook Islands Ministry of Infrastructure and Planning responsible for leading on the quantitative analysis and report writing was required to take unplanned leave (for family reasons) at the time this work was meant to be done; and (ii) the engineer on the Cook Islands PACC CBA team was working on a number of other projects and did not have capacity to dedicate the time to the CBA that was needed. Another contributing factor may have been that the CBA was perhaps perceived by the National Project Management Unit as an overall regional project requirement, rather than appreciating its value in improving the quality of their pilot project.

SUCCESS FACTOR 1 – 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.

OUTCOME 1 – The Cook Islands PACC team are developing a maintenance programme as well as a community awareness programme as recommended by the CBA. However, due largely to time constraints, the recommendation to undertake further engineering analysis was not taken on board.

4.2. Samoa

Problem statement

The village of Tafitoala on the south coast of Upolu, Samoa is vulnerable to coastal erosion (Government of Samoa, 2007; PACC, 2009).

Satellite imagery taken for the years 1954 and 1999[43] indicates that land loss in the area classified as a 'coastal erosion hazard zone' has averaged approximately 0.66 metres per year over that period. Community consultations suggest erosion rates since 1999 could be as high as 1 metre per year in this area (Government of Samoa , 2007).

Within the Tafitoala coastal erosion hazard zone there are six residential houses[44] (from 2010 satellite maps). There are also a number of environmental assets (beach, marine ecosystem) within and near the erosion hazard zone which are considered important for tourism (surfing, snorkelling, and general beach recreation) and subsistence fishing. No substantial food crops or subsistence gardens are located within this area.

43 These are the most recent registered area images available from the Land Management Division (LMD) of the Ministry of Natural Resources and Environment (MNRE).

44 In 2007 there were five residential houses.

Causes and drivers of the coastal erosion problem

Coastal erosion is a natural process that occurs through the actions of currents and waves and results in the loss of sediment in some places and accretion in others (Centre for Oceans Solutions, 2013)[45]. At Tafitoala, this process is not well understood.

Human activity also contributes to the coastal erosion problem at Tafitoala. This occurs through:

- Unregulated sand-mining at the river estuary mouth and nearby villages (Government of Samoa, 2007); and
- Deforestation along the streamside and rivers, which increases sediment flow into the ocean and contributes to degrading of coral ecosystems. This in turn increases the actions of currents and waves in the beach area and thus erosion (Government of Samoa, 2007).

Further, climate change may exacerbate coastal erosion risks through sea level rise and potentially more frequent and severe storms and associated current and wave action (Centre for Oceans Solutions, 2013). According to the Pacific Climate Change Science Program (PCCSP, 2011), there is moderate confidence that sea level will rise by between 5 and 15 cm by 2030 in Samoa. Tropical cyclone frequencies are forecasted to decrease over the 21st century but the proportion of cyclones that are 'most severe' are expected to increase (PCCSP, 2011).

Options

The option that has been implemented for the Samoa PACC pilot project is a seawall. This was constructed in 2010. The seawall is also supported by several 'soft' adaptation measures comprising:

- Replanting of salt-tolerant coastal plants to create natural barriers along the coastline;
- Replanting along streamside from ridge to coastline.

The selection of a seawall for the Samoa PACC pilot project was based on recommendations in the Coastal Infrastructure Management (CIM) Plan for the Tafitoala area (Government of Samoa, 2007).

The engineering design of the Tafitoala seawall follows the design at Saoluafata Village (north coast of Upolu), which was implemented as part of the Capacity Building for the Development of Adaptation Measures in Pacific Island Countries (CBDAMPIC) project in 2006. Details of engineering design are provided in the Engineering Plan, available from the Samoa Ministry of Natural Resources and Environment (MNRE) upon request.

Costs and benefits

The costs of the seawall considered in the CBA relate to construction and maintenance costs of the seawall as well as losses related to damages/impacts on environmental assets (caused by the seawall construction).

The capital and maintenance costs covered in the CBA included the following:

- Materials, equipment hire, and labour expense (SAT$462,530, according to PACC quarterly reporting documentation);
- Maintenance cost (SAT$15,726 per year[46]).

Environmental impacts include damage to the beach area where the seawall is now situated as well as potential damage to beach/land in neighbouring villages and near-shore marine ecosystems associated with alteration of long-shore drift patterns. The losses relating to damage to these 'environmental assets' were considered as four separate categories: (i) tourism revenues; (ii) subsistence fish catches; (iii) land at neighbouring villages; and (iv) social amenity of beach areas by local community members. However, due to the lack of (scientific) understanding

45 http://centerforoceansolutions.org/climate/impacts/cumulative-impacts/coastal-erosion/

46 Exact figures are not available so this expense is approximated at 3.4% of sea wall construction costs. This 3.4% is based on a paper on the economics of coastal adaptation (King, McGregor and Whittet, 2010).

of the potential impacts on assets and related environmental services,[47] these loss categories could not valued in the CBA.

The benefit streams were considered as three separate categories.

The first benefit category related to avoided loss of land at the project site. The seawall was estimated to reduce the rate of coastal erosion in the erosion hazard zone from 0.66 m/year without any intervention[48] to 0 m/year with the seawall (MNRE, 2010). The value of this land area saved[49] was then approximated using average market prices of land sold in the Apia region (SAT$207/m^2).[50]

The second benefit category considered was the avoided costs of relocating residential houses situated in the coastal erosion hazard zone. This was approximated using the average cost of a family house[51] in Apia (SAT$36,311)[52] and assuming that the six houses currently located in the erosion hazard zone would all relocate over the next 25 years in an even/linear fashion without the seawall (i.e. under the 'business as usual' scenario).

Finally, avoided damage and losses associated with storm surge events were considered. The seawall is expected to provide significant flood protection benefits to households in Tafitoala.[53] These include avoided damages to residential houses, avoided clean-up costs, avoided income loss, and reduced stress. Due to limited resources and time, these benefits were not measured.

Results and sensitivity analysis

Once costs and benefits of the project options were quantified, the data were used to calculate the net benefit of the pilot project. This net benefit is expressed in terms of net present value (NPV) and benefit:cost ratio (BCR). The results are presented in Table 4.2A on the following page. Note: the NPV results are in expressed in 2010 Samoan tala ($SAT) values and the seawall was assumed to function for 25 years.

47 An environmental screening checklist was completed by Isikuki Punivalu & Associates Ltd for the Samoa Ministry of Natural Resources and Environment (MNRE, 2010) in accordance with the *Environmental Impact Assessment (EIA) Regulations 2007* which assessed the significance of impacts on environmental assets as low. However, this assessment is inconsistent with a rapid assessment of sea wall and break wall proposals at Satupuala, Safata, Aofaga, and Utulaelae undertaken by SOPAC, which advised that deeper investigation into the impacts of engineering solutions, particularly on sedimentary systems, is needed before such solutions are implemented (Webb, 2010).

48 This is a conservative estimate consistent with erosion rates approximated for the period 1954 to 1999 using satellite imagery.

49 This is calculated by multiplying the rate of erosion (0.66m/year by the length of the seawall (800m) by the expected useful life of the sea-wall (25 years).
0.65 x 800 x 25 = 520 m^2

50 This was based on average values reported in Fairbarn-Dunlop (2000) for the period 1999–2000, adjusted for inflation (5.7%/year) and converted to Samoa tala using an exchange rate of 2.3. Apia land sale value was used as there are no records available for the Tafitoala area.

51 Note, this is the cost of the housing infrastructure only. It does not include contents or land values.

52 Woodruff (2008) adjusted for inflation.

53 The vulnerability of Samoan coastal settlements to the effects of climate change and sea level rise were highlighted through the impacts of Tropical Cyclones Ofa (1990) and Val (1991).

TABLE 4.2A. Samoa PACC CBA results

	Economic results
(1) Present value of costs at 8% discount rate	
Capital construction costs	*$462,530*
Maintenance costs	*$167,872*
Environmental impacts	*Not valued*
	$630,402
(2) Present value of benefits at 8% discount rate	
Avoided loss of land from erosion	*$1,276,006*
Avoided relocation costs related to erosion	*$101,741*
Avoided damages and losses from flooding	*Not valued*
	1,377,748
(3) NPV = (2– (1)	$747,346
(4) BCR = (2) / (1)	2.19

A sensitivity analysis was also conducted. The sensitivity tests involved changing the magnitude of key variables and measuring impact on the NPV and BCR. Key variables tested were: (i) the rate of coastal erosion without any intervention. This was modelled as 1.33 metres per year – a rate considered possible if climate change effects are 'worst-case'; (ii) the effectiveness of seawall in mitigating erosion. This was modelled as reducing erosion rate to 0.33 metres per year rather than 0 metres per year, which is considered possible if the seawall is not properly maintained; (iii) the value of land. This was modelled at 50% lower than values used for Apia. Tafitoala is some 46 km from Apia; and (iv) the discount rate. A 4% discount rate was modelled in addition to the 8% rate used by Samoa Government so as to be consistent with other PACC CBAs. 4% is the worldwide average real market interest observed for the last 150 years.

The sensitivity analysis results are presented in Table 4.2B below.

TABLE 4.2B. Samoa PACC CBA sensitivity analysis results

Variables	Primary results		Sensitivity test results	
	NPV ($)	BCR	NPV ($)	BCR
(i) Rate of coastal erosion without intervention (1.33 m/ year)	$747,346	2.19	$2,042,686	4.24
(ii) Effectiveness of seawall in mitigating erosion (erosion rate with seawall is 0.33 m/year)	$747,346	2.19	$109,343	1.17
(iii) Value of land (50% of Apia prices)	$747,346	2.19	$109,343	1.17
(iv) Discount rate (4%)	$747,346	2.19	$1,253,379	2.77

Conclusions

The CBA undertaken so far has provided very preliminary results only. As shown in Table 4.2B, the results are very sensitive to assumptions about the baseline rate of coastal erosion, the effectiveness of the seawall in reducing erosion, as well as the value of land. Moreover, environmental impacts from seawall construction and the coastal flood protection benefits generated from the seawall have not been considered in detail – and these items are potentially very important. As such, no clear conclusions or recommendations can be made about replication or up-scaling of the PACC project seawall design at this stage.

The CBA does however highlight a number of important knowledge gaps which should be a focus for next steps in coastal zone management in Samoa (and before further seawalls are constructed). These are:

- Scientific understanding of the coastal erosion process(es). This includes understanding of sedimentary systems, how sedimentary systems may change under the effects or any structure development and of changing climate variables and longer climate change trend, and the relationship(s) of these sedimentary systems with key coastal ecosystems. It also includes understanding of sand-mining activities, deforestation and other upland activities and their effects on coastal erosion processes.
- Scientific understanding of the effects of seawalls on sedimentary systems and flow through impacts on environmental assets and related services and functions.
- Economic and social values of both natural environmental assets and development located in coastal zones.

Much of the abovementioned knowledge gaps are complex and cannot reasonably be filled by the PACC project alone. However, given the high risks to coastal zones in Samoa and the concern for maladaptation, this research/policy effort is needed and should be a priority for future work. It is therefore recommended that opportunities are sought to work collaboratively with other government departments and development partners to strategically fill these knowledge gaps. Information/knowledge could then be used to formulate a National Framework for Coastal Zone Management for Samoa or the Samoa SIM Plan.

Success factors, key challenges and outcomes of CBA implementation

SUCCESS FACTOR 1 – A key success factor of the CBA was active participation and contributions from the economist based at the Samoa Ministry of Natural Resources and Environment. This meant that CBA results and findings were well understood and there was a good amount of 'ownership' of the CBA.

CHALLENGE 1 – A difficulty experienced for conducting the Samoa PACC CBA was that there was no engineer or scientific expertise in the Samoa PACC CBA team. This was needed to help provide important technical inputs in these areas.

CHALLENGE 2 – Another difficulty experienced was that there was lack of information and data to input to the analysis. As mentioned in the summary there was inadequate scientific information on sedimentary processes, the effects of seawalls on these processes, and the flow through impacts on environmental assets and related services. Nor was there monitoring and evaluation information that could be inputted. In addition, a CBA study of seawalls at the project site had apparently been undertaken by the World Bank to inform the Coastal Infrastructure Management Plan (2007). However the report for this study could not be located by Samoa Government staff.

CHALLENGE 3 – A further difficulty was that technical backstopping was insufficient. The Samoa CBA was perhaps the most complex CBA undertaken for the PACC CBA work programme and substantial analytical effort is required to properly assess projects of this type (at least for the first one). This effort/support could not be provided within the timeframe and resources available to the PACC.

OUTCOME 1 – The Samoa PACC took on board the advice of the CBA to undertake further research and analysis before replicating or up-scaling seawalls.

PART 5 LESSONS LEARNED AND AREAS FOR FUTURE WORK

In terms of planning and management of the PACC CBA exercises, there were a number of things that worked well, and also a number of things that did not work so well. This section summarises the success factors and challenges of implementing the PACC CBAs that are outlined in each of the PACC CBA summaries in parts 2, 3 and 4 above. Based on these success factors and challenges it will then draw key lessons learned that can hopefully be taken on board by PICT government officials for CBAs of projects in the future. This will help to ensure that future CBAs are as useful as possible, projects developed are high quality, and allocation of resources (especially human resources, which are in short supply in the Pacific region) to these project(s) is a worthwhile investment.

Success factors

The primary success factor was active participation by country officials. Where officials were interested and keen to be involved, this helped to ensure that available data and information were inputted to the analysis; officials understood the technical elements of the analysis and could communicate and discuss the analysis with stakeholders and decision makers (independent of consultant support); and this knowledge was 'owned' and effectively used. A good example of this was the Tuvalu PACC CBA, where an economist from the Tuvalu Ministry of Finance & Economic Development led on quantitative analysis and report writing.

Active participation was enhanced by technical assistance being delivered over a longer period of time, rather than a one-off, 10 day country visit. This point was highlighted by participants in feedback provided in the conclusion workshop. Here participants suggested that future technical backstopping should aim to be for an extended period of time – 3 to 4 months – in order to provide sufficient amounts of contact and to allow flexibility for officials to continue working on their other work commitments.

A second related success factor was conduct and participation in the CBA by a multidisciplinary team including for example economists, meteorologists, sector planners, engineers, and environmental scientists as appropriate. Where a functional multidisciplinary team was successfully set up, this helped to ensure important technical inputs from relevant fields were incorporated and that there was a broader understanding of the purpose and results of the CBA (and hence agreement on findings) among stakeholders.

One part of the interdisciplinary working arrangements that was reported to work well was the use of the CBA workplan template/tool developed for the PACC CBA work programme. This template essentially follows each step of the CBA procedure and outlines the types of information that will need to be collected and collated at each stage. It also contains key questions and considerations that promote optimal utility of this template. This resource is given in Appendix 1.2 and in the Pacific CBA Guideline.

Challenges

Key challenges were the following.

1. Late introduction of CBA into the PACC programme. This meant that CBAs were too late to inform selection of some PACC pilot projects. It also meant there was little time available to complete the CBAs and communicate findings.

2. Lack of background assessments and data to input to the CBAs. For a number of the PACC CBAs, vulnerability analysis and other situational and problem analysis type assessments had not been completed prior to beginning the quantitative elements of the CBA. Also, in some cases relevant assessments and reports were known to exist but due to poor knowledge management systems within countries, could not be located for the analysis. Further, inadequate baseline data had been collected for PACC pilot projects wanting to undertake *ex-post* CBAs to evaluate their project (as opposed to *ex-ante* CBAs to appraise project options before implementation). These challenges

are rooted principally in the complex and multi-level setup of the PACC project, and overall project challenges and delays in establishing the needed national project management arrangements in 14 participating countries aligned with the regional project frame.

3. Difficulty attracting people with technical skills to participate in multidisciplinary work teams. Most difficult to find were officials with an economics background. Engineers were also difficult to involve for some CBAs. This can partly be explained by the relatively narrow invitation process followed. In accordance with CROP/SPREP protocols, participants were formally invited through a circular sent to SPREP focal points as well as the Secretary of Treasury and relevant line ministries for each participating country.
4. Limited number of days that some technical backstopping personnel, particularly consultants, were able to provide technical support to help participants conduct the CBA of their PACC pilot project.
5. Difficulties communicating CBA results and findings. These difficulties were most evident where there was not strong technical expertise within PACC CBA teams (and who did not have a sound understanding of the process) and where there was not ongoing technical backstopping available to support these activities.

Based on these experiences, the following key lessons are drawn for the planning and management aspects of the PACC CBAs.

- *CBA must be introduced and planned for in the early stages of project development if it is to effectively inform decision making on the selection and design of identified adaptation options and approaches. This involves, among other things, educating stakeholders about* the purpose of CBA and where it fits into the project cycle, budgeting for time and technical inputs needed to complete an appropriately detailed analysis, and scheduling activities and outputs to communicate the results/findings of the CBA to stakeholders and decision makers.
- *Substantial effort is required to formulate multidisciplinary teams to oversee and conduct the CBA*. This must include technical officials such as economists, engineers, sectoral planners and meteorologists as appropriate. This is also important for ensuring that government officials understand the technical elements of the analysis; are able to communicate and discuss this analysis with stakeholders and decision makers (independent of consultant support); and this knowledge is 'owned' and effectively used. Additional actions that could be taken in the future to help formulate teams include identifying individuals through networks and including their names in formal invitation letters. A joint CROP agency approach (if CROP agencies are involved) in issuing invitations may assist in future programmes as a single CROP agency does not have established relationships with all relevant ministries required to undertake an inter-disciplinary approach – e.g. finance ministries (PIFS), agriculture (SPC), and environment (SPREP). Identifying and engaging leaders/champions of CBA within PIC governments would also help to ensure the right officials are nominated and that they are able to fully participate.
- *Good knowledge/information management systems within country governments (and CROP and regional development partner organisations) make the conduct of CBA far less resource and time intensive, and contribute significantly to more accurate (and hence useful) CBAs.* Increased involvement in the conduct of technical assessment reports by PIC government officials will increase ownership of reports which in turn is expected to improve management of this knowledge/information.
- *Situational and problem analyses, such as vulnerability assessments, should be completed thoroughly and systematically prior to starting the quantitative aspects of CBA.* This helps to clarify the nature and causes of the project problem, and that identified options to address it are appropriate. This is needed to ensure the project objective is correctly specified and the CBA is thus correctly constructed. It is also needed to provide important input data and information to the quantitative aspects of the CBA.
- *CBA provides an important 'gate-keeping' function. The systematic CBA procedure serves to identify key data and knowledge gaps which are important for making sound, evidence-based decisions about project option selection and design. Adequate time needs to be provided to allow for collection and analysis of such identified information gaps prior to project implementation.*

- *Adequate technical backstopping arrangements are critical*. To promote ownership of assessments, technical backstopping should be provided with capacity building and skill development as a key focus, in addition to also developing a robust CBA report. Ideally, country officials should lead on the conduct of analysis and report writing as much as possible, with technical backstopping guiding this process and providing 'review and comment' in a continuous and needs-based mentoring fashion. The use of detailed Terms of Reference (for in-kind support, CROP economists, consultants, or whoever) and the CBA work planning tool can help ensure support provided meets the needs of countries. Technical backstopping appears to be more effective (at producing better quality CBAs, achieving active participation by government officials, and maximising country 'ownership' and use of CBA findings) if it is provided over a longer period of time so that government officials have adequate opportunity to participate in the conduct of the analysis.
- *Communication features should be a core and prominent part of future CBA exercises.* Adequate time and resources must be budgeted for communication activities. These would include, but not be limited to: (i) preparing briefing papers on the CBA; (ii) delivering short presentations to decisions makers, including preparations to answer questions and defend the analysis; (iii) incorporating CBA information into Cabinet submissions; and (iv) incorporating CBA information into project proposal documents to be submitted to donors. These could be included as outputs of any technical support.

Future work

The work undertaken as part of the PACC CBA work programme clearly demonstrates the benefits of applying CBA early in the project cycle and PIC government officials leading and/or being actively involved in the conduct of CBAs for their projects.

To achieve wider and more effective use of CBA in the future – in order to improve the evidence base and quality of adaptation or any other development projects – further training of government officials and strengthening of institutional decision-making processes is needed. The report of the PACC CBA work programme capacity building experiences and lessons learned(PACC Technical Report 1) suggests a number of ways in which to do this. Moreover, a concept for a more systematic regional training programme on CBA is currently under development, through the regional partnership established under the PACC CBA work programme.

Environmental valuation[54] studies for the Pacific region are another important area of future work. Information from these valuation studies provides key inputs for many CBAs in the Pacific (and other project appraisal methods) but they are not usually undertaken because they are time consuming and expensive. As such, a more systematic and coordinated approach to conducting these studies in the region is needed with a view to eventually developing a pool of values that can be used for 'benefits transfer'[55] applications.

Finally, there may also be merit in extending CBA from project-level assessments to sector-level economic analyses – in order to inform design of sector strategies, policies and plans. This level of analysis is a relatively new area of work for the Pacific region context and thus should be pursued on a trial basis. Water sector plans on atoll countries seem a very good first application, given the magnitude of water scarcity and water quality problems in many PICTs, especially in the context of climate change. Part of this should include economic valuation of water resources/water demands.

54 Environmental valuation techniques attempt to value environmental goods and services in monetary terms so they can be considered in decision-making and management.

55 Benefits transfer is a method of environmental valuation. It is a time-saving and cost-effective approach that uses economic values from previous environmental valuation studies and applies them to address current policy challenges.

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APPENDIX 1.1 PROGRAMME LOGIC OF PACC CBA WORK PROGRAMME

ASSUMPTIONS →

- CBA will be practical and useful
- PACC countries will have capacity to apply basic CBA
- Individual staff will have the skills to learn and apply CBA
- There is regional expertise available to provide technical backstopping support
- PACC will have resources to introduce and support CBA effectively

INPUTS →

PACC funding and resources

Capacities/skills of up to 13 pilot project sites

SPREP Economist (COMSEC)

UNDP

Interagency collaboration

SPC

GIZ

Consultant Support

ACTIVITIES/ OUTPUTS →

Sub-regional workshops

CBA workplans

Technical backstopping to implement CBA workplans

- SPREP
- SPC/GIZ
- UNDP
- Consultants

PACC country CBA reports

Consolidated knowledge product(s)

CBA Guidelines

Evaluation

OUTCOMES →

- Increased CBA knowledge and skills
- Improved PACC pilot project selection and design
- Improved PACC pilot project evaluation
- Increased funding secured for up-scaling of worthwhile projects

LONG-TERM IMPACTS

Reduction of community's climate change and disaster risks in the water, food security (agriculture), and coastal sectors.

Pacific Island Countries (PICs) have greater capacity to address their priorities in responding to climate change

APPENDIX 1.2 COST–BENEFIT ANALYSIS (CBA) WORKPLAN TEMPLATE

1. Determine the objectives of the CBA

Problem

Short description of the problem that the project(s) is trying to address. This should include information on the nature and extent of the problem, making sure to reference sources of this information.

Cause(s) of problem

- Typically, there are multiple causes and drivers contributing to a given problem. List the main causes and drivers of the problem under consideration and include a preliminary appraisal of the relative importance of each of these causes and drivers.
- The changing frequency and intensity of climate variables (e.g. rainfall, cyclone) should be included here as one of the potential drivers of the problem (i.e. climate change risk considerations). This may be a large or small part of the problem at hand.

Objective of project

- Short statement of the project objective. If possible, this objective should be specific and directly link to one or more of the causes of the problem.

Options

List and briefly describe each of the options that have been identified to achieve the stated objective.

Check that these options:

- were identified through a thorough process, including review of what has been done in other parts of the country and the broader Pacific region as well as consultations with communities
- clearly align with the project objective (and causes/drivers of the problem)
- are feasible given the budget constraint for the project (if applicable)
- options are clearly distinguishable from one another
- there are enough options identified to provide the decision maker with real scope for exercising choice

Objective(s) of CBA

Based on the above-listed information on the problem and options, specify the objectives for the CBA.

For most CBAs, the primary objective is to determine whether the benefits of a project option outweigh its cost and by how much relative to other alternatives. The purpose of this is to (i) determine whether the proposed project is (or was) a sound investment (justification/feasibility); and/or (ii) compare between alternative project options (rank and prioritise).

There may also be other objectives of the CBA that are specific to the problem or project options under consideration, which should also be incorporated. For example, the party commissioning the analysis may also be interested in better understanding the significance of potential environmental impacts of a project proposal and, if substantial, what design modifications can be made or complementary measures introduced to improve the project.

The objectives of the CBA should be clearly and correctly specified at the outset, and all parties involved should agree on these. This provides the direction for the analysis work.

2. Identify costs and benefits – with and without analysis

This section lists the various costs and benefits that need to be considered for each of the options identified to achieve the stated project objective (and thus address the identified problem). Importantly, one of the options should be the status quo or baseline scenario (i.e. costs and benefits to be experienced if none of the projects were implemented – 'without project' scenario).

This information should be summarised in the 'with and without analysis' table below.

Baseline – without project	Project option 1	Project option 2	Project option 3
	Costs		
	Benefits		

The left hand column of this table qualitatively describes what inputs, outputs, and outcomes/impacts relevant to the project problem are expected to be experienced without any project options being implemented. That is, what would likely happen if we just followed 'business as usual' taking into consideration any trends observed for the relevant impacts/outcomes, trends observed for the identified causes and drivers of the problem including population growth, and whether any other activities are planned which seek to address the same or similar problems in the same area.

The right hand column(s) of the table describes these same inputs, outputs and outcomes/impacts for the scenario where the proposed project option(s) are implemented relative to the without-project scenario (i.e. what change will the project result in against 'business as usual'). The right hand column also includes the additional inputs required to implement the project options. These are the up-front (i.e. capital) and operational costs of the project option.

The right hand column further includes any other outcomes/impacts associated with the project options that are either not the intended focus of the project or are experienced by third party stakeholder groups. These can be either positive (a benefit) or negative (a cost).

3. Measure and value costs and benefits

This section should detail the data/information needed to estimate each of the costs and benefits identified in the with and without analysis, and list where this data/information can be sourced. It should also state the intended 'method' that will be used to value each of the cost and benefit items identified.

This information should be summarised in a table like the one below.

PROJECT OPTION 1

Cost/benefit	Valuation method	Data required	Source of data
Cost 1			
Cost 2			
Benefit 1			
Benefit 2			

Note that some cost and benefit items may be too abstract to measure or too small a consideration to justify going to the effort of collecting data and undertaking valuation analysis. For these items, the table should list 'qualitatively describe and discuss' and briefly outline the reasons why this item will not be valued in monetary terms.

4. Aggregate costs and benefits

This section details how costs and benefits will be aggregated/computed over time. Key matters to be outlined here include:

- choice of discount rate;
- the (economic efficiency) measures that will be estimated (most commonly for government projects this is net present value and benefit:cost ratio); and
- how options with different lifespans will be compared.

5. Conduct sensitivity analysis

List key parameters (e.g. length of drought period) where there is a significant amount of uncertainty.

Describe how these uncertainties will be tested through a sensitivity analysis – e.g. through testing of upper and lower bound values of these parameters.

Outline the basis for selecting values used in the sensitivity analysis.

6. Consider equity and distributional implications

Identify which stakeholder groups will incur costs and which stakeholder groups will accrue benefits for each major cost and benefit category.

This information should be summarised in a table like the one below.

Cost/benefit	Stakeholder group 1	Stakeholder group 2	Stakeholder group 3
Cost 1			
Cost 2			
Benefit 1			
Benefit 2			

Comment/assess whether impacts on certain stakeholder groups may merit special consideration (e.g. costs borne by low socio-economic groups).

Further comment on whether distributional effects will likely cause political or other issues that may threaten the successful implementation of the project – and could benefit from refinements to project design.

TIMELINE

Action	Date	Responsibility
Data collection		
Data analysis		
Draft CBA report		
Peer review		
Final CBA report		
Briefing paper on CBA report		
Presentation on CBA report to ***xyz***		
Incorporation of CBA report results and findings in project proposal and Cabinet submission		

APPENDIX 1.3 EXPECTED VALUE ANALYSIS AND SENSITIVITY ANALYSIS ILLUSTRATION

Risk

Expected value is a mathematical combination of payoffs and probabilities and is commonly used to assess risk. The expected value calculation is illustrated below by assigning some numbers to a hypothetical agriculture example.

In this example, an agriculture project faces a situation of risk at the beginning of the growing season at which time it is not known whether rainfall (a random event) will be sufficient to grow the planned crop (benefit) or not.

Let's suppose the value of crop production in a year where there is 'sufficient rainfall' to grow a crop is $100 and that historically this level of rainfall occurs 9 out of every 10 years on average. Also suppose that the value of crop production in years where there is 'insufficient rainfall' is $0 and that historically this level of rainfall has occurred 1 year out of every 10 years on average.

The expected value of annual crop production is thus calculated as follows:

		value crop prodn in 'sufficient rainfall' year		**value crop prodn 'insuff rainfall' year**
Exp value of crop prodn	=	**x**	+	**x**
		annual prob of 'sufficient rainfall' occurring		**annl prob of 'insuff rainfall' occurring**
	=	**$100 x 9/10**	+	**$0 x 1/10**
	=	**$100 x 90**	+	**$0 x 10%**
	=	**$90**	+	**$0**
	=	**$90**		

More information on this approach is available in the many textbooks and resources on cost–benefit analysis, decision-tree analysis etc. One good resource is *Cost-Benefit Analysis: Concepts and Practice* by Boardman et al. (2010).

Uncertainty

In the medium to long term, probabilities for weather events (e.g. low levels of rainfall) are expected to change due to climate change. However, the magnitude – and direction for some climate variables – of this change is unknown. That is, the probabilities of future weather events in the medium-long term is uncertain.

To account for this uncertainty in the PACC CBAs, sensitivity analysis was applied. The sensitivity analysis procedure for climate uncertainty is illustrated for the hypothetical agriculture example mentioned above.

For this part of the example, let's suppose that the probabilities of 'sufficient rainfall' to grow a crop under climate change are uncertain but are roughly expected to range between 80% (lower rainfall climate scenario) and 95% (higher rainfall climate scenario). Sensitivity analysis recalculates the expected value of crop production for each potential climate change scenario. This calculation is illustrated below.

Exp value of crop (low climate change scenario)	=	**$100 x 80%**	+	**$0 x 20%**
	=	**$80**	+	**$0**
	=	**$80**		
Exp value of crop (higher climate change scenario)	=	**$100 x 95%**	+	**$0 x 5%**
	=	**$95**	+	**$0**
	=	**$95**		

These different benefit values would then be inputted to the full CBA to see if aggregate results materially change or not. Readers are encouraged to refer to Step 5 of the Pacific CBA Guideline for a more comprehensive explanation of the sensitivity analysis procedure and how changes to CBA results should be interpreted.

APPENDIX 1.4 DETERMINING A RANGE OF PLAUSIBLE WEATHER EVENT PROBABILITIES FOR USE IN CBA SENSITIVITY ANALYSIS

The Pacific Climate Futures Tool is an excellent resource to help determine plausible medium- and long-term weather event probabilities for use in risk analysis. The Climate Futures Tool can be found at http://www.pacificclimatefutures.net/.

Climate variables that the Pacific Climate Futures Tool can help provide estimates for are mean rainfall, evaporation, surface temperature, humidity and wind speed. It cannot provide estimates for extreme rainfall, sea level rise, or cyclone.

The suggested approach for using the Climate Futures Tool for risk analysis is to determine 'most likely', 'worst case' and 'best case' climate futures for the climate variable of interest. This should ideally be done using the 'Advanced' mode of the Climate Futures Tool, which will identify a single model to represent each of these future climate scenarios.

Output information of the Climate Futures Tool will be in the form of for example –5% to +5% change in annual rainfall. This information should then be applied to historical data sets to give absolute values. Probability information (e.g. likelihood rainfall will be 'insufficient' to grow crop) can then be derived from these adjusted historical data sets.

This process of determining climate future projections and applying changes to historical data sets should be undertaken three times, corresponding to the 'most likely', 'worst case', and 'best case' scenarios. 'Most likely' projections would be used in the central analysis. 'Worst case' and 'best case' scenarios would be used in the sensitivity analysis.

Assistance should be sought from country Met offices to generate these climate futures projections and then translate projections to probability information that you need for the CBA. While this explanation may sound a bit complicated, if you talk to your Met officers about what you are after, what you need it for, and show them this Appendix then they will be able to help.

The Pacific Met Desk can also work with country Met offices to generate climate futures projections if this assistance is needed.

APPENDIX 2.1 GROUNDWATER CONTAMINATION AND RELATED HEALTH IMPACT SCENARIOS FOR NIUE PACC CBA

Current and future risks of groundwater supply contamination are not well understood. In turn, accurate forecasts of water-related health impacts from these contamination risks are not possible – at least not without doing further in-depth studies.

Nonetheless, to get a basic understanding of the potential health impacts from groundwater supply contamination and the benefits of reducing these impacts, indicative scenarios are developed. These are based on scenarios developed by Talagi (2011) in his assessment of groundwater infrastructure upgrades and water quality monitoring activities (to improve public water supply quality/safety) in Niue. This scenario is summarised as follows:

- As a result of microbial and other lens contamination, there will be an outbreak of water-borne disease in five years, which will recur every two years, with an average of six cases of residents falling sick per outbreak and requiring hospitalisation.
- There will be two mild occurrences per month (24 per year) of water-borne illness requiring consultation with a doctor and medication, which will occur yearly, and increase by two cases every year.
- Cases requiring hospitalisation will be assumed to require a week off work, and every consultation case will require two days off work.

In light of the high uncertainty of future contamination risks, especially relating to climate hazards, two additional without-project scenarios are developed for this analysis:

- *Low contamination future.* This scenario describes a future where frequency and intensity of cyclone and extreme rainfall hazards are lower than the Talagi scenario. It also describes a scenario where land use activities do not materially increase from what it is now (i.e. extensive taro exporting does not resume). Under this scenario, the probability of an outbreak of water-borne disease is reduced to once every four years. Also, the incidence of mild health cases is 50% lower than the 'Talagi contamination scenario'. That is, start at 12 cases of mild water-borne illness per year and increase by one per year.
- *High contamination future.* This scenario describes a future where frequency and intensity of cyclone and extreme rainfall hazards are higher than the Talagi scenario. As described in the Problem section of this report, this is less likely but nonetheless very possible. This future also describes a future where land use activities increase significantly over time. Under this scenario, the probability of an outbreak of water-borne disease increases over time – starting at once every two years in 2018, increasing to once every 1.5 years in 2023, increasing again to once every year in 2027 and so forth. Also, the incidence of mild health cases is 50% higher than the Talagi contamination scenario (that is, start at 36 and increase by three per year).

With the household rainwater tank project, supply of good quality water from household rainwater tanks is expected to reduce incidence of mild and serious water-related sickness (relative to the without project scenario) by 50%. This is based on the expectation that households will preferentially consume (good quality) water from rainwater tanks for drinking such that exposure to contaminated water is reduced by 50%.

With the repair/replacement of leaking pipes project, groundwater supply contamination risks will be reduced such that the incidence of mild and serious water-related sickness (relative to the without-project scenario) will be reduced by 61%. This is crudely based on the cost-share of system pipework costs[56] relative to total costs of

56 This cost is NZ$586,000 and is a lower-bound estimate provided by Clinton Chapman (personal communication, July 2012) and is based on an asset valuation undertaken in 2010.

priority measures in Drinking Water Safety Plan (DWSP)[57] and the assumption made in Talagi (2011) that priority DWSP measures will reduce water-related health costs by 100% relative to the without-project scenario.

Repair of leaking pipes is also expected to increased consumer confidence in the quality of groundwater supply and so is expected to reduce the amount of imported bottled water purchased.

The extent to which purchases of imported bottled water is expected to be reduced is 30.5%. Similar to water-borne disease, this is crudely based on the cost-share of pipe work and reticulation and improvement costs relative to total costs of priority measures in DWSP[58] and the assumption made in Talagi (2011) that priority DWSP measures will reduce purchase of imported bottled water by 50% relative to current levels.

57 Total costs of priority measures in Drinking Water Safety Plan are NZ$960,950. Pipe work costs as a share of total costs is 0. 61 (586,000/960,950 = 0.61).

58 Pipe work is NZ$586,000 (Clinton Chapman, personal communication, July 2012). Total costs of priority measures in Drinking Water Safety Plan are NZ$960,950. Pipe work costs as a share of total costs is 0.61.

APPENDIX 2.2

COSTS AND QUANTITY OF ADDITIONAL WATER SUPPLY ESTIMATES FOR RMI PACC PROJECT OPTIONS

TABLE A2.2.1. Cost information for RMI PACC project options.

Option	Cost
1. Reline reservoir	Construction costs is estimated at $123,781 for tank 4 of the current system (Fabtech) Annual materials and labour costs for maintenance are $35 and $43 respectively (Fabtech, MWSC) The liner is expected to last 30 years (Fabtech, MWSC)
2. Evaporation cover	Construction cost is estimated at $50,873 for tank 3 of the current system (Fabtech) Annual materials and labour costs for maintenance are $98 and $47 respectively (Fabtech, MWSC) The evaporation cover is expected to last 30 years (Fabtech, MWSC)
3. Repair and replace leaking pipes	Material and labour costs for construction are estimated at $267,080 and $192,298 respectively (MWSC) Annual materials and labour costs for maintenance are $26,708 and $64,099 respectively (MWSC) The repaired and replaced pipes are expected to last 30 years (MWSC)
4. Airport runway maintenance a. Valves b. Cracks	a. Annual labour costs for valves are $3,240 (MWSC) b. Material and labour costs for construction are estimated at $50,000 and $960 respectively (MWSC) Annual materials and labour costs for maintenance are $2,000 and $2,880 respectively (MWSC) The repaired cracks are expected to last 30 years (MWSC)
5. Expand airport catchment a. Geomembrane b. Asphalt	a. Construction costs are $200,000 (MWSC) Material and labour costs for construction are estimated at $100 and $1,248 respectively (MWSC) The geomembrane is expected to last 5 years (MWSC) b. Construction costs are $2,000,000 (MWSC) Material and labour costs for construction are estimated at $100 and $1,248 respectively (MWSC) The asphalt is expected to last 30 years (MWSC)

TABLE A2.2.2. Data and assumptions for calculating quantity of additional water supply for RMI PACC pilot project options.

Option	Data and assumptions for calculating quantity of additional supply
1. Reline reservoir	Current leakage from tank 4 is estimated to be 49,964 m^3 a year. This is based on two tests run by MWSC (first between 29 June–1July 2012, second 2–4 July 2012). Water loss was calculated as: tank surface area (3,456 m^2) x change in height (0.04 m^2) – evaporation rate for tank (12 m^3/day) + rainfall capture for tank (18.61 m^3/day) x number of days in 1 year (365). This level of leakage is assumed to continue for the next 30 years. The new liner is assumed to reduce leakage losses altogether.
2. Evaporation cover	Current evaporation from tank 3 is estimated to be 4,704 m^3 a year. This is calculated by multiplying the surface area of tank 3 (3,790 m^2; MWSC) by the estimated daily evaporation rate (3.44 mm/day; Engineers report, MWSC) by the number of days in 1 year (365). This level of evaporation is assumed to continue for the next 30 years. The new evaporation covers is assumed to completely mitigate evaporation losses. It is further assumed that rainfall hitting the covers will not be captured.
3. Repair and replace leaking pipes	Current leakage losses from pipes is estimated to be 173,514 m^3/year. This is calculated by multiplying the current volume of water flowing through the pipes (347,000 m^3/year; MWSC) by the leakage rate (estimated at 50%; MWSC). This level of leakage was assumed to continue into the future. With repair and replacement of leaking pipes, the leakage rate from pipes is expected to be reduced to 25% of flow volumes (MWSC), which equates to a water saving of 86,757 m^3.
4. Airport runway maintenance a. Valves b. Cracks	a. Water capture losses on airport runway associated with king tide events is currently estimated at around 15,619 m^3/year. This is calculated by multiplying the number of days per year which king tide events occur (6 days) by the average daily rainfall rate (9.2 mm) by the area of runway catchment (263,000 m^2; Mark Stege, personal communication) by the current water capture efficiency of the runway (0.80; MWSC). The analysis assumes that these losses will continue at this level for the next 30 years without any PACC intervention. With the valves, it is expected that all water capture losses associated with king tide events will be avoided. No water supply from this option is valued at scarcity value for the central analysis. b. Water capture losses on the airport runway associated with cracks is currently estimated at 440,583 m^3/year. This is calculated by multiplying the potential volume of water capture runway (550,729 m^3)[59] by the efficiency factor for the current runway catchment with existing cracks (estimated at 80%). The analysis assumes that these losses will continue at this level for the next 30 years without any PACC intervention. With the intervention to fix the cracks, efficiency of capture is expected to increase to 85% (MWSC). This equates to a water saving of 27,536 m^3. No water is valued at scarcity value.
5. Expand airport catchment a. Geomembrane b. Asphalt	The additional water that would be captured from expanding the airport catchment is estimated at 194,907 m^3/year. This is calculated by multiplying the additional area of catchment (58,000 m^2; MWSC) by rainfall rates (9.2 mm/day) by the efficiency factor (assumed to be 80%). The areas and capture efficiency of both the geomembrane and asphalt construction options are expected to be the same and so additional water generated on an annual basis from these options are the same.

59 This is calculated by the area of the runway catchment (263,000 m^2) by net rainfall (i.e. rainfall minus evaporation). Historical monthly rainfall and evaporation data was used in the analysis.

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. The programme began in 2009 and is scheduled to end in December 2014. 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 TECHNICAL REPORTS

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.

PACC

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