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Economic dimensions of relocation as an adaptation strategy to climate change:

A case study of the Narikoso Relocation Project, Fiji

James Jolliffe, Geoscience Division, the Pacific Community

Suva, Fiji, 2016

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Executive summary

Barriers to private adaptation to coastal inundation in the remote community of Narikoso, Fiji appear to be a lack of financial resources and access to information concerning community-based adaptation options. Government intervention to correct for these impediments to adaptation is justified if it is efficient. Given the Government of Fiji's current focus on relocation as an adaptation strategy, the costs and benefits of relocation as a means of removing the barriers to private adaptation are analysed here.

The costs of the Narikoso Relocation Project outweigh the benefits and, in this regard, the project provides a negative economic payoff for Fiji. When comparing the benefits of the relocation with its expected costs, there appears to be no case for government intervention through relocation in Narikoso. If relocation is to be pursued, then it should be relocating the Red Zone as this scenario represents the highest value, quantified intervention overall (albeit in combination with negative net benefits). The analysis also suggests that building a new seawall results in a worse negative economic payoff than any of the relocation scenarios.

The negative payoff is due, in part, to the decision to relocate being made before detailed assessments were carried out. The national relocation guidelines must ensure that — prior to a decision being made — community-specific risks and barriers to private adaptation are identified, assessed and understood. This requires a holistic vulnerability assessment drawing from local knowledge and expertise in the sciences, land affairs and rural development. Such an approach would help ensure that relocation only occurs in communities where it is the most efficient option available for removing the impediments to private adaptation.

Based on this evidence, the Government of Fiji should consider adopting relocation guidelines that focus on removing the barriers to private adaptation and allow for relocation only when it is the most efficient solution. Options designed to remove constraints to adaptive capacity are likely to be broader than simply relocation. The resettlement of households most vulnerable to coastal inundation, rather than the relocation of entire communities to especially demarcated land, should also be considered. The costs of relocating entire communities are likely to be substantial in comparison to the benefits that accrue through resettling vulnerable households only.

Given the apparent inefficiency of hard adaptation options in this case study, the national relocation guidelines should ensure that the economics of soft adaptation options are analysed as well as hard ones. Considering the costs and benefits of alternative strategies such as soft adaptation options would provide a clearer understanding of when and where relocation is suitable.

Although relocation or building a new seawall are not favourable options, there is some evidence that other aspects of the Narikoso Relocation Project — such as livelihood interventions — show promise and their efficacy should be tested on a broader scale. Data collected through household questionnaires suggests that the community is producing high values of food for subsistence. The apparent success of the community's farms could be developed to provide a source of income through the sale of surplus food to nearby tourist resorts.

1. Introduction

This report details the methodology and results of a cost–benefit analysis (CBA) of 'hard' options to adapt to coastal inundation in the remote village of Narikoso, Fiji. It is the culmination of a partnership between the Climate Change Division (CCD) of the Government of Fiji and the Geoscience Division of the Pacific Community (SPC) in late 2015 and early 2016.

1.1 Context

Small islands are highly vulnerable to current and future climate-related changes. Sea level rise, in combination with extreme sea level events such as storm surges, poses a particular threat to communities living in low-lying coastal areas. The risks of flooding and erosion are likely to add to other challenges such as improving human health and reducing adaptive capacity, and will generally impede on lives and livelihoods (Nurse et al. 2014).

In response, the Government of Fiji has developed a National Climate Change Policy to guide efforts to address climate change issues locally (Government of Fiji 2012). The CCD, which currently sits within the Strategic Planning Office of the Ministry of Finance, is responsible for the overall oversight of the policy and the coordination of climate change-related projects. Adaptation is a core objective of the policy. Strategies to achieve adaptation include the incorporation of climate change risks to urban and rural planning and the development of sustainable adaptation systems that are culturally acceptable. The policy does not mention relocation as an adaptation strategy.

Perhaps in response to continued mean sea level rise in Fiji since the policy was ratified in 2012 (BoM and CSIRO 2014), the government has adopted relocation as an adaptation option for communities most at risk from the impacts of climate change. After repeated flooding, the community of Vunidogoloa on the island of Vanua Levu was relocated 2 km inland in 2013, and cyclone damage resulted in the relocation of Denimanu Village on Yadua Island to higher land (also in 2013). In 2015, Prime Minister Voreqe Bainimarama announced that 800 communities and 40 settlements required relocation due to the impacts of climate change (Fiji Times 2015). Cyclone Winston, a Category 5 cyclone that made landfall in Fiji on 20 February 2016 killed 44 people and destroyed 949 houses on Koro Island and partially damaged 44. Of the 14 communities affected by Cyclone Winston on Koro, 12 have requested relocation (Relocation Taskforce 2016).

Despite increasing interest in relocation as an adaptation option, no formal policy exists yet on community relocations due to climate change.1 In 2015, the CCD and other key government ministries began developing official guidelines with the assistance of the Pacific Community (SPC)/German Agency for International Cooperation (GIZ) project 'Coping with Climate Change in the Pacific Islands Region'. A number of principles were decided on early in the consultation period, including that relocation should be a last-resort option after all other adaptation options have been exhausted. Once completed, the national guidelines will provide a comprehensive process by which the decision to relocate may be made.

1.2 Purpose

To inform the development of the national relocation guidelines, the CCD requested SPC's assistance with assessing the economic dimensions of relocation due to climate change using the village of Narikoso as a case study. The analysis provides a view of the costs and benefits — both direct and indirect — of relocation and building a new seawall as adaptation options in rural coastal communities in Fiji.

1 The Government of Fiji is, however, committed to creating a national relocation guideline at the first National Climate Change Summit in 2012.

The request also relates to ongoing efforts of the Government of Fiji to mainstream the use of economics to plan and assess development projects affected by climate change. Officials from the CCD attended a Pacific Cost–Benefit Analysis Initiative[2] workshop in April 2015 where participants were taken through the cost–benefit analysis (CBA) process. To further consolidate this training, a CBA team consisting of one economist from SPC and one official from CCD was formed in early November 2015. The team has worked together on the development of a CBA of the proposed relocation of the Narikoso community, including collaborating closely on community consultations. The analysis was supported by the SPC/United States Agency for International Development (USAID) project 'Vegetation and land cover mapping and improving food security for building resilience to a changing climate in Pacific Island communities'.

2. Background

2.1 Narikoso

Narikoso Village is on the southeastern side of Ono Island, the second largest of a string of four inhabited islands in Kadavu Province in Fiji. The Kadavu Group is a volcanic archipelago characterised by thickly vegetated hilly peaks and encompassed by coral reefs. Ono is separated from larger Kadavu Island by the Ono Channel and lies approximately 45 nautical miles south of Suva on the main island of Viti Levu through Kadavu Passage (Fig. 1).

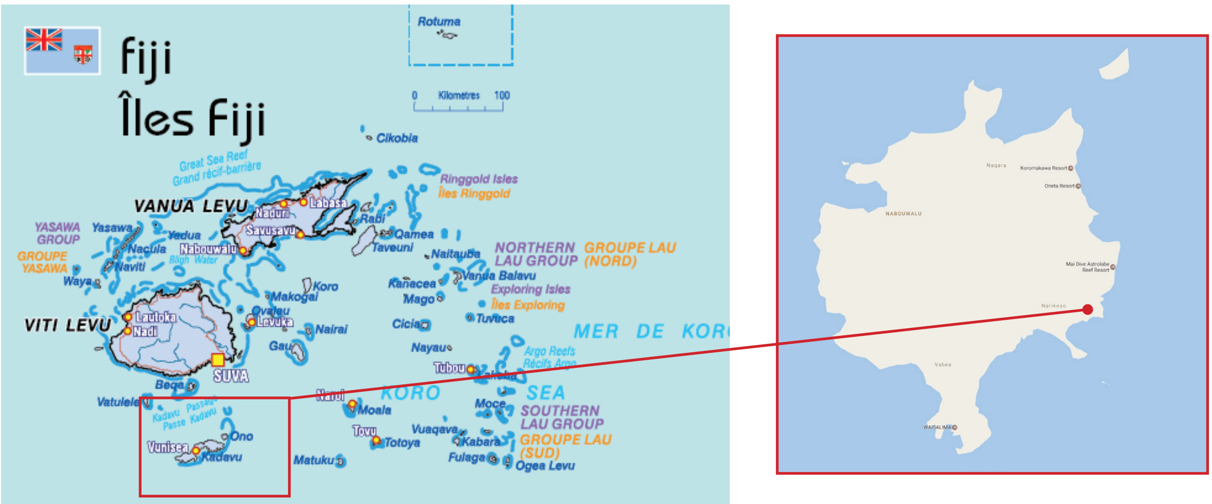

Figure 1. Kadavu and Ono islands in relation to Fiji's capital, Suva, and the main island, Viti Levu. Source: worldatlas.com

Narikoso Village consists of 25 households with a population that varies between 95 and 105. There are two churches, one Methodist and one Catholic, but other Christian denominations are also present (Narikoso Development Committee 2013). For the vast majority of households (95%), sewage is disposed of through water reticulation systems that flush to septic tanks. One small store provides access to basic commodities but the closest commercial centre is 45 minutes away by boat in Kavala Bay on Kadavu Island. Electricity is provided

2 The P-CBA initiative assists Pacific Island countries in the use of cost–benefit analysis as a tool to support climate-resilient decision-making. Partners include the Pacific Islands Forum Secretariat, the Pacific Community, the Secretariat of the Pacific Regional Environment Programme, United Nations Development Programme, Deutsche Gesellshaft für Internationale Zusammenarbeit, the United States Agency for International Development Climate Change Adaptation Project 'Preparation Facility for Asia and the Pacific Asia-Pacific Project', and the University of the South Pacific.

by a diesel generator that runs from 07:00 to 08:00 and 17:00 to 18:00 when, and if, the motor is functioning. Most households own one or more solar lanterns that provide basic lighting when the generator is off (Mineral Resources Division 2013).

There are no roads connecting Narikoso to other communities on Ono Island. Transport is often slow and limited to boat travel on the sea or footpaths through the interior of the island. The relative remoteness of Narikoso has resulted in a low economic base with much of the community relying on subsistence fishing and agriculture. A source of tourism income exists through Narikoso's close proximity to the Great Astrolabe Reef, a 100 km-long pristine barrier reef system that is popular with recreational divers. Nearby resorts servicing this attraction provide regular employment for some of the villagers and purchase small volumes of crops and fish that are surplus to the community's requirements. According to the Forestry Department, the village has a pine tree plantation of 46.5 ha. Otherwise, alternative economic opportunities are limited.

2.2 Problem analysis

Narikoso is a low-lying coastal community with the majority of households located in close proximity to the shoreline. As a result of coastal erosion, there has been an increase in the impact of inundation events — a situation expected to be exacerbated by sea level rise (Appendix A provides a summary of the coastal oceanography of Narikoso found in Bosserelle et al. 2015b). Currently, a seawall built by the community in the 1960s has been breached and seawater reaches the foundations of properties closest to the waterfront at every high tide (see photos in Appendix B). Moreover, inundation of households is compounded during king tides and extreme weather events such as storm surges.

After visiting Narikoso in 2013, the Mineral Resources Division (MRD) of the Government of Fiji labelled the two rows of houses closest to the shoreline as being within the Red Zone. There are 15 inhabited houses located within the Red Zone — including eight on the Front Line closest to the shoreline — which is demarcated by red cr0ss-hatching in Figure 2. Unless action is taken, the Red Zone will remain vulnerable to the impacts of coastal erosion.

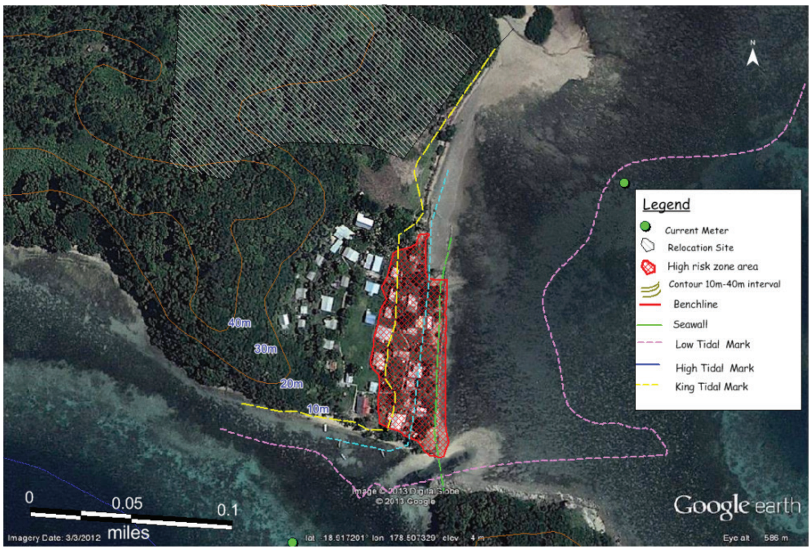

Figure 2. Narikoso vulnerability map showing the Red Zone. Source: Mineral Resources Division 2013

2.2.1 *Private and public adaptation to vulnerability*

The degree to which coastal erosion causes damage (due to inundation) and the ability of households to adapt are important components of vulnerability (Noble et al. 2014). Effective adaptation to coastal erosion in Narikoso would entail making the necessary adjustments to reduce damages in response to the observed impact. Adaptation could take many forms and be conducted by various actors: it could be undertaken *privately* by individuals, households or the entire community, or be planned and implemented *publicly* by a central government.

Households have, insofar, been unable to adapt to coastal erosion, and as a result, the community requested the assistance of the Government of Fiji in 2012. Understanding why private adaptation has failed in Narikoso is necessary to determine whether or not government intervention is justified.

2.2.2 Adaptive capacity constraints

Adaptive capacity in this case has been defined as the community's ability to adapt to the impacts of coastal erosion in the face of ongoing sea level rise. In general, it is likely to change with time and be influenced by a number of factors (Noble et al. 2014). From an economic perspective, government intervention could be justified if barriers to the community's adaptive capacity exist and the benefits of intervening outweigh the costs of doing so (Chambwera et al 2014). Community consultations in Narikoso revealed a number of potential barriers that limit adaptive capacity (see Section 3.1.2). Although by no means exhaustive, these barriers can be thought of as contributing to the underlying causes of the community's ongoing vulnerability to coastal erosion.
Narikoso is a relatively cash-poor community without access to sufficient economic resources. Although some money raised through community activities is sent to Suva and saved in a bank account, few households have an account of their own or any disposable income from which money could be saved. With limited access to savings and credit markets, it is unlikely the community would be able to fund large-scale adaptation efforts, even if it is in their own interests.

In addition, community members were not able to identify alternatives to capital intensive and, therefore, high cost adaptation options.[3] This implies a lack of access to information regarding both the likely impact of climate change on the village and other solutions such as those suggested in Appendix A. Unless the government or other public authorities support its dissemination, the costs to the community of acquiring such information would likely represent a significant barrier (Chambwera et al. 2014).

2.3 Government intervention and relocation

The constraints to adaptive capacity listed above provide some reasoning as to why private adaptation has failed in Narikoso. A lack of access to finance has left the community unable to afford to adapt, and information problems exist such that simple measures have not been pursued. Government intervention could be justified if it corrects such barriers and is cost-effective.

This CBA investigates whether or not relocation is an efficient use of resources to correct for the barriers to adaptation in Narikoso. The building of a new seawall has also been assessed following community consultations in which it was suggested as an alternative strategy.

2.3.1 Relocation as an adaptation strategy in Narikoso

Shortly after the initial request for assistance in 2012, the Government of Fiji decided to clear land adjacent to the current village site so that every household could be moved uphill and away from the coastline (referred to as Site A in the remainder of the analysis). A total of FJD 200,000 was contributed by the Office of the Prime Minister,

3 The only adaptation option other than relocation suggested by the community during focus group discussions was building a new seawall (see Appendix C for the questionnaire used).

and the Royal Fiji Military Forces excavated a plot of land 150 metres from the original village site. It is not clear how the decision to relocate was made, or how the excavated site was chosen, but the decision-makers would not have had the benefit of detailed studies carried out later. Figure 3 displays two satellite images, one taken before the new village site was excavated (03 March 2012) and one afterwards (01 September 2013). The buildings visible populate the current Narikoso Village site.

Figure 3. Satellite image of Narikoso Village before and after Site A excavations. Source: GoogleEarth

Although providing land for the relocation of a number of households, Site A is not large enough to house the entire village. Also, soon after the excavations had been completed, the land was deemed too unstable for construction to begin. The Narikoso Village Development Committee, the community organisation responsible for such matters, therefore requested further assistance from the CCD in preparation for relocation.

With the financial and technical assistance of the SPC/GIZ project 'Coping with Climate Change in the Pacific Islands Region', the CCD brought together multiple government departments, ministries and development partners under a coordinating body named the Relocation Taskforce. The various activities performed by the Relocation Taskforce have become known as the Narikoso Relocation Project. These activities have included:

- a preliminary vulnerability and adaptation to climate change assessment;
- geological and geotechnical assessments of the land, ocean and freshwater sources; and
- various initiatives to prepare the community for relocation.

2.4 Relocation and land tenure in Fiji

Land tenure in Fiji is divided into three broad groupings (Department of Town and Country Planning 2015). State Land administered by the Department of Lands makes up 7% of Fiji's landmass. Freehold land, the titles to which can be bought, sold or leased freely accounts for approximately 10%. The remainder and vast majority is titled iTaukei land, and covers approximately 83% of all land.

iTaukei land is owned communally by traditional land owning units, the most common unit being a *mataqali* (clan). An iTaukei village can consist of a number of *mataqali*s and every village member belongs to one. Most *mataqali*s have the customary rights to a portion of reserve land surrounding the location of their home village, although some reserved land is designated *lotu* (for the church) and, therefore, not necessarily for the use of villagers. *Mataqali* land may be used for growing food or *yaqona*, some may be un-utilised or it can be leased to external parties. The iTaukei Land Trust Board and the Fiji Land Bank are the statutory bodies charged with administering leasing arrangements on behalf of the land owners.

If an iTaukei village is to be relocated, then due process needs to be followed. Typically, this requires the permission of whichever *mataqali* owns the proposed new village site and legal demarcation performed by the iTaukei Land and Fisheries Commission. Narikoso is an iTaukei village on iTaukei lands. The new village site has been released by two of four *mataqali*s that make up the village. Demarcation has taken place but the formal process to transfer land rights has yet to be carried out.

This CBA should be read as an assessment of relocation on iTaukei land only. The differing land tenure structures of freehold and State lands mean the results of this analysis cannot be viewed as transferrable, and further study is required. Importantly, this analysis does not consider relocation from informal settlements and should not be read as doing so.

3. Methodology

Upon instruction of the CCD, several plausible relocation scenarios and the building of a new seawall are tested for economic efficiency through CBA. This analysis only considers engineered approaches that involve constructing new infrastructure. Such interventions are often referred to as 'hard' adaptation options (Sovacool 2011). Despite the focus on hard options in this analysis, 'soft' strategies such as ecosystem-based approaches should not be ignored as potential solutions, and a proper analysis of the costs and benefits should be conducted.[4]

3.1 Cost–benefit analysis

CBA is a framework for identifying, valuing and comparing the costs and benefits of a project or policy from a 'whole-of-society' perspective. The societal aspect of CBA differentiates it from other forms of analysis (e.g. financial) because it involves valuing, at least qualitatively, the wider impacts of a project that may otherwise be ignored, such as social and environmental effects.

Broadly speaking, this CBA has followed the seven steps outlined in 'Cost–benefit analysis for natural resource management in the Pacific – A guide' (Buncle et al. 2013), the core text used during Pacific Cost–Benefit Analysis Initiative capacity building workshops such as that attended by the CCD (see Section 1.2). For further information on the technical details of CBA, refer to Buncle et al. (2013) or the many other publicly available CBA guides (e.g. New Zealand Government 2015). If performed to the standard that is set by the guidelines, CBA provides a systematic and holistic contribution to the decision-making process; systematic because a set of distinct steps are undertaken and holistic because all known impacts are considered.

One key step in the CBA process regards the quantification of a project's impacts in monetary terms. In order for a fair comparison to be made, all costs and benefits associated with the relocation project should be valued monetarily. However, many impacts, such as those associated with the environment, are not easily expressed in dollar terms. For example, it is clear that the removal of mangroves to make way for building houses has a negative environmental impact. The monetary quantification of this impact is not immediately clear as mangroves are not normally bought and sold and, therefore, have no recognisable market value.
This CBA has monetarily quantified as many impacts as has been possible given the time and resources devoted to it. Impacts that have not been valued are described in detail and a judgement has been made on their potential magnitude. Importantly, the quantitative results of the CBA only reflect the costs and benefits that have been valued monetarily. It is, therefore, crucial that these results are considered in conjunction with the additional costs and benefits outlined qualitatively.

4 Indeed, previous studies in other parts of Fiji have indicated that adaptation plans focused on soft approaches, such as replanting mangroves, provide high net economic benefits compared to hard approaches (Rao 2013).

3.2 Data

Data for this analysis was sourced through discussions with government officials, published materials and — to ensure the costs and benefits faced by the community were included — a series of dedicated community consultations. A household questionnaire and a set of focus group questions were devised.[5] The CBA team then travelled to Narikoso to conduct interviews with community leaders and carry out the survey between 18 and 26 November 2015.

Focus groups were conducted among separate groups of men, women and youth to gauge opinions on the coastal inundation, potential relocation of the village, and other interventions. The results of the focus groups highlighted the costs and benefits faced by the community.

In order to study the community's views in more detail, a representative from every household present during the interview period (25 households, 18 men and 7 women) was surveyed. The questions attempted to ascertain household details, household incomes and expenditures, health issues, and household vulnerabilities due to coastal inundation. The results of the survey have provided information used in the valuation of costs and benefits. A number of key findings from the survey, which have fed into assumptions or valuations, are provided in Table 1.

In addition to the focus groups and household questionnaire, the CBA team conducted interviews with a number of key informants. Those interviewed included the head of the Narikoso Development Committee, the village's treasurer, and the heads of various community groups. The details revealed during the interviews have provided insight that has further guided the identification and valuation of the costs and benefits of the relocation project.

Table 1. Key findings from household questionnaire.

Factor	Value	Reasoning
Average working days per week	6	People try not to work on Sundays
Number of households	25	Number of households inhabited during survey
Number of households in red zone	15	17 households in total but only 15 inhabited
Population	111	Reported number of household occupants
Average subsistence production		Estimated from household questionnaire
Village monthly total	$42,057	
Per household per working day	$61	
Average cash income (Red Zone)		Estimated from household questionnaire
Yearly total	$107,652	
Per household per working day	$23	
Household damages due to inundation (Red Zone)		Estimated from household questionnaire
Average days spent fixing things per year	8	
Average amount spent on repairs per year	$940	

5 Contact the author (jamesj@spc.int) to request survey questions.

4. Incorporating climate change

The following section explains the method by which climate change risk has been dealt with in this analysis. Although not a truly scientific approach to measuring the climate-related risks faced by the community, the method is straight forward and it is hoped that the following may be replicated by government officials with limited resources.

4.1 Modelling climate change

Assessing adaptation options for Narikoso requires an understanding of the likely effects that climate change will have on the Narikoso community. Unfortunately, confidence in the outcomes of global climate models (GCMs) decreases as the modelled area gets smaller and locally influential factors create uncertainty (BoM and CSIRO 2014). For this reason, projecting the precise effects of climate change on an area the size of Narikoso is not possible with acceptable levels of accuracy.

On the other hand, the Pacific region is experiencing well documented climatic changes, and projections exist at the national level for 15 Pacific Island countries (PICs), including Fiji, through the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) programme. Table 2 displays a summary of climate projections for Fiji indicated by the average of 26 well-performing GCM models studied by PACCSAP (BoM and CSIRO 2014). The direction of change is given a confidence rating based on how many of the models projected the change.

Table 2. Climate projections for Fiji.

Variable	Change	Confidence
Average and high temperatures	Increase	Medium
Extreme temperatures	Increase	Very high
Wet season rainfall	Increase	Low
Extreme rainfall frequency	Increase	High
Drought time	Decrease	Low
Ocean acidification	Continue	Very high
Coral bleaching risk	Increase	Medium
Sea level rise	Continue	Very high
Wave height (wet season)	Decrease	Low
Wave height (dry season)	Increase	Low
Tropical cyclone formation	Decrease	High
Tropical cyclone intensity	Increase (global)	Medium

Source: BoM and CSIRO 2014

4.2 Climate change risks in Narikoso

Typically, coastal erosion and inundation occur when large waves coincide with large tides such as perigean spring tides (otherwise known as 'king' tides). Studies based on computer modelling suggest that wave conditions in Narikoso are often slight and the mean annual wave height has changed little since 1979 (Bosserelle et al. 2015a). This may imply that there is less risk of inundation in Narikoso than in other communities living within proximity to larger wave climates. However, higher sea levels increase the risk of wave processes causing erosion and subsequent inundation. Overall, it seems likely that these factors will act to exacerbate vulnerabilities already faced by the community. This study assumes that inundation as a result of coastal erosion in Narikoso will continue to increase with climate change.

The climate variables considered relevant in this analysis are shown in Table 3 alongside a comment on whether their impact has been included in the analysis.[6] To provide a rough estimate of the impact of climate change on inundation in Narikoso, climate projections have been used to estimate sea level rise there. The results of this exercise have been used to quantify the increase in damages faced by the community if no adaptation takes place.

Implicitly, an assumption has been made that there is a relationship between sea level rise, inundation as a result of coastal erosion, and the resultant damages in Narikoso. Specifically, it is assumed that the damage caused by coastal inundation increases on a one-to-one basis with sea level rise. This relationship is by no means certain so its impact on the results of the analysis is tested in 'Section 10: Sensitivity analysis'. The following section describes how sea level rise in Narikoso was determined for the purposes of this analysis.

Table 3. Climate variables considered in analysis.

Variable	Change	Confidence	Impact on inundation
Sea level rise	Continue	Very high	Positive impact
Wave height (wet/dry)	Decrease/Increase	Low/Low	Balanced: no effect
Cyclone (formation/intensity)	Decrease/Increase	High/Medium	Balanced: no effect

4.3 Estimating sea level rise in Narikoso

4.3.1 Historical sea levels

The Australian government's Bureau of Meteorology Pacific Sea Level Monitoring (PSLM) project aims to generate accurate long-term sea level records among 14 participating PICs. In Fiji, the project collects information on sea level and tides from a permanent tide-gauge located off the coast of Lautoka.[7] Figure 4 plots the observed mean sea level at Lautoka between 1995 and 2015 in dark green and a trend line in light green. On average, observed mean sea level has increased by around 9 cm over the 20-year period, from 1.23 m in 1995 to 1.32 m in 2015.

Data collected by PSLM in Lautoka have been used to approximate the historical mean sea level and potential future mean sea levels in Narikoso. The average mean sea level in Lautoka between 1995 and 2015 was 1.27 m. This is taken as the baseline from which sea levels are projected in Narikoso.

6 In this cost–benefit analysis, the effect of tropical cyclones is assumed to remain the same because the impact of increasing cyclone intensity is assumed to be balanced by the projected decrease in frequency. The same assumption has been applied to wave height, which is projected to increase in the dry season but decrease in the wet season.

7 Lautoka is on the northwest coast of Viti Levu, the largest island in the Fiji Group, and far away from Narikoso (see map in Section 2.1). Caution should be exercised when extrapolating from a single tide gauge. In addition, the Lautoka tide gauge record has not been corrected for land movement or other parameters that may influence reported rates (Bureau of Meteorology 2016).

Figure 4. Historical annual mean sea levels in Fiji measured at Lautoka tidal gauge.

4.3.2 Projecting sea level rise in Narikoso

Consistent with the International Panel on Climate Change (IPCC 2013) methods, the climate projections collated by PACCSAP are based on the results of four greenhouse gas concentration trajectories called representative concentration pathways (RCPs). The RCPs allow analysis of climatic changes according to a range of possible emissions pathways; from a scenario where emissions are effectively constrained (RCP 2.6) to one where emissions are very high (RCP 8.5). As such, projections of sea level rise under RCP 2.6 are much smaller than under RCP 8.5 (see Table 4). It is, therefore, important to select projections from the RCP deemed most likely to occur.

Table 4. Annual mean sea level above the 1995–2015 mean by representative concentration pathways (RCPs) in centimeters (cm).

	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Year	Very Low Emissions	Low emissions	Medium emissions	Very high emissions
2030	13 (8-18)	13 (8-18)	13 (8-17)	13 (8-18)
2050	22 (14-31)	23 (14-31)	22 (14-31)	25 (17-35)
2070	31 (19-44)	35 (22-48)	35 (22-47)	42 (28-58)
2090	41 (24-58)	47 (29-67)	49 (30-68)	64 (41-88)
Medium confidence. 5–95% range of uncertainty in brackets				
Source: BoM and CSIRO 2014				

The Paris Agreement, signed by all 195 participating member states, obligates parties to reduce their output of greenhouse gases with the aim of keeping global warming to below 2^{0}C by 2100 (UNFCC 2015). This roughly corresponds to RCP 6.0, which translates to projections of mean global temperature increases of 2.2^{0}C between 2081 and 2100. This analysis, therefore, uses projections of sea level rise in Fiji from RCP 6.0.

To approximate sea level rise in Narikoso, the annual mean sea levels under RCP 6.0 in Table 4 are added to the average mean sea level in Lautoka between 1995 and 2015. The resultant mean sea levels are plotted in Figure 5 as dark green spots. The light green trend line provides an estimation of the mean sea level at any given point in time over the period. The year-on-year difference between points on the line has been used as a proxy for the increase in damages in Narikoso as a result of the impact of sea level rise.[8]

8 This assumption has been used because of the absence of other useable data for Narikoso. It provides an illustration of the potential impacts of sea level rise in Narikoso. In practice, the estimation should be treated with caution and considered an underestimation of the potential impact. The effects of higher damages are explored in 'Section 10: Sensitivity analysis'.

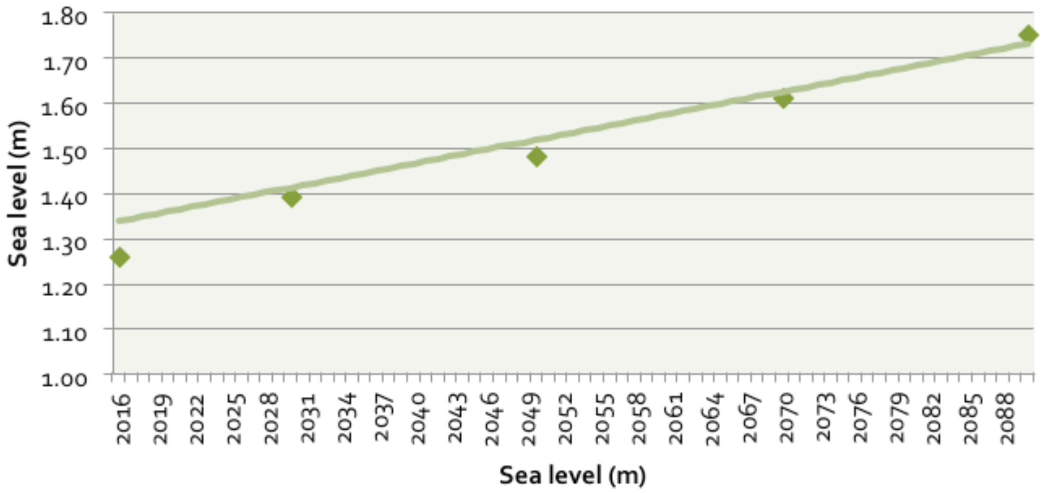

Figure 5. Estimated future mean sea levels in Narikoso under RCP 6.0.

5. Incorporating disaster risk

The low-lying nature of Narikoso Village leaves it vulnerable to the impacts of extreme weather events such as storm surges caused by tropical cyclones. According to the Pacific Damage and Loss Database (PDaLo; www.pdalo.net), at least three tropical cyclones have caused damage on Kadavu since 1973. Relocating the village is likely to reduce the risk of a disaster such as a cyclone, or the resulting storm surge, affecting the community. It is, therefore, necessary to consider the impact of reducing this risk in the analysis.

Data from the Pacific Risk Information System (PacRIS)[9] database has been used to estimate the impact of a storm surge caused by a potential tropical cyclone. Although the data collected and modelled by the Pacific Catastrophe Risk and Financing Initiative (PCRAFI) in Fiji is extensive, none exists for Narikoso specifically. The CBA team, therefore, conducted a survey of the buildings in the village and used it as the basis for several manipulations of PacRIS data that exist for Kadavu. The full methodology used in this analysis has been detailed in 'Appendix C: Estimating avoided damage from a disaster'.

5.1 Estimating a risk curve for Narikoso

The buildings survey collected data on the size, location and construction type of each building. The replacement costs of similar buildings on Kadavu included in the PacRIS database were then used as proxies for the replacement costs of buildings in Narikoso Village. The level of damage (measured as a percentage of total replacement costs) that would occur in the event of cyclones of differing intensities was estimated using the PCRAFI Damage Tool. Finally, a risk curve calculated by PCRAFI for the whole of Kadavu was used to estimate the relationship between the likelihood of cyclones of differing intensities occurring, and the value of the damage caused (see 'Appendix C: Estimating avoided damage from a disaster' for further explanation).

9 The PacRIS database was constructed by the Pacific Catastrophe Risk and Financing Initiative (PCRAFI), an SPC, World Bank and Asian Development Bank project that provides Pacific Island countries with disaster risk modelling tools. The project assesses the potential effects of wind, floods and storm surges induced by tropical cyclones, as well as earthquakes and tsunamis.

Figure 6 indicates the potential value of damage caused by cyclones in Narikoso, and has been relied on to value the benefits of relocation. The advantage of using a risk curve is that it allows for the impact of cyclones to be included in the analysis according to the likelihood of their occurrence (represented by mean return period).[10] For example, the risk curve in Figure 6 indicates that losses of just over FJD 450,000 are expected to be exceeded once every 100 years on average. Or, the losses associated with a 1-in-every-50 year event are expected to be around FJD 275,000. Alternatively, this could be read as a 1% chance that Narikoso will experience building damages equal to around FJD 450,000 (or a 2% chance of around FJD 275,000) in any given year.

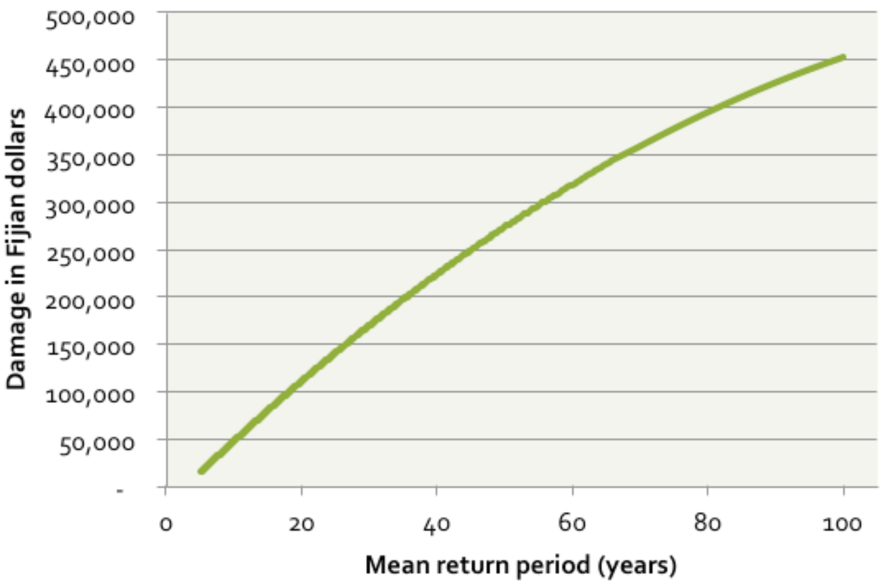

Figure 6. Buildings-only risk curve for Narikoso estimated using data from the Pacific Catastrophe Risk and Financing Initiative /PacRIS.

6. Scenarios analysed

The following scenarios outline the potential interventions that were analysed. The costs and benefits of these options are measured against a scenario where no intervention takes place. Each scenario includes the impact of climate change and disaster risk discussed in the previous sections.

6.1 No Further Intervention

Under this scenario, the government does not intervene further to correct for the barriers to private adaptation in Narikoso and, therefore, nothing is done to prevent the impacts of inundation on the village. Households in the Red Zone continue to be damaged and require fixing, a problem exacerbated year after year by climate change. This means less time is spent by villagers attending to subsistence activities or earning incomes. The community also remains exposed to the dangers of an extreme weather event. The resources spent excavating and stabilising Site A effectively go to waste.

10 However, the risk profile has been created using a number of assumptions, including, but not limited to, an identical relationship between risk and replacement costs in Narikoso and the areas of Kadavu modelled through the Pacific Catastrophe Risk and Financing Initiative. A multitude of complexities exist, meaning that this almost certainly would not be true in reality. But in the absence of accurate risk modelling for Narikoso, this method provides at least a basic approximation of the community's exposure to disaster risk.

6.2 Relocate Entire Village

This scenario is based on the proposal to relocate 25 households as identified in a Project Design Document (PDD) prepared by the CCD and submitted to the European Union/GIZ Adapting to Climate Change and Sustainable Energy programme (Climate Change Division 2015). To accommodate the entire village, more land than Site A would need to be cleared and prepared for building houses. The total additional land required would be called Site B. As identified in the PDD, the community would require access to a new water source and one would need to be identified and developed. Because every household would be away from the shoreline and above sea level, they would no longer face the impacts of coastal inundation. According to the Government of Fiji, the new houses would be resilient to severe events such as cyclones. The provision of climate resilient housing, in addition to relocation, reduces the risk of losses caused by an extreme weather event.

6.3 Relocate Red Zone

Under this scenario, only the 15 Red Zone households would be relocated (see Section 2.2 for description of the Red Zone). Because more houses must be built than will fit onto Site A, further groundwork would be required (albeit less than what would be necessary if the entire village were to be relocated). The land required — if only the Red Zone is relocated — would be called Site C to differentiate it from the larger piece of land that would be required if the entire village is relocated (see Table 5). As per the PDD, a new water source must still be identified and developed. The Red Zone would be relocated away from the shoreline and, therefore, would no longer face the impacts of coastal inundation. However, climate resilient housing and relocation reduce the risk of losses caused by an extreme weather event in the Red Zone only.

6.4 Relocate Front Line

This scenario is similar to relocating the Red Zone, but only the eight households situated on the shoreline would be relocated. No groundwork beyond that already completed for Site A would be required but, as per the PDD, a new water source would need to be developed. Households located on the Front Line would no longer face the impacts of coastal inundation but the rest of the Red Zone would continue to do so. The risk of losses due to an extreme event would be reduced but only for the eight houses that are relocated. For clarity, Table 5 summarises the site requirements for each relocation scenario.

Table 5. Site requirements for each relocation scenario.

	Relocation scenario		
	Entire Village	Red Zone	Front Line
Site A	O	O	O
Site B	×	-	-
site C	-	×	-

6.5 Build New Seawall

As suggested by a number of respondents to the community surveys and focus groups carried out in Narikoso, this scenario is concerned with removing the old seawall and building a better functioning replacement. The new seawall would need to be better engineered than the current one to take account of the coastal oceanography of Narikoso. In this regard, the new seawall would reduce the rate of coastal erosion as opposed to the no further intervention scenario. Nonetheless, some disruption of natural coastal processes is inevitable.

The new seawall would protect the village from the impacts of coastal inundation, but would do little to prevent damage caused by an extreme event because any expected storm surge would far exceed the specifications of the wall. The seawall would need to be maintained regularly to prevent wear and tear compounded by sea level rise, which would otherwise render the seawall increasingly ineffective as time went on. Because no households would be relocated, no new water source would need to be developed.

7. Identifying costs and benefits

Once the scenarios were characterised, the impacts of each were identified using a combination of consultations with key stakeholders and the survey. Impacts that might occur within a 50-year time frame were considered.[11] Any negative impact was considered to be a cost, and any positive impact a benefit. The main costs were concerned with clearing the land for the new site and building new households. The main benefits were associated with removing households from the path of coastal inundation and resultant harm. Environmental and social impacts were also considered.

Table 6 indicates the costs and benefits that were identified and to which scenario they apply. The impacts described below are not equal in magnitude for each scenario and the table should not be read in this way. For example, the cost of building housing applies whether the entire village, the Red Zone or just the Front Line are relocated. However, the total cost of building housing in each of these scenarios will differ with the number of houses required to be built. The costs of clearing and stabilising appear in every relocation scenario because the land is necessary in all scenarios.

Despite the fact the land will not be used if no further intervention takes place, the cost of clearing and stabilising Site A is still included because the money has already been spent. Under this scenario, the expenditure effectively goes to waste. The inclusion of these costs in the no further intervention scenario is justified because, in line with Buncle et al (2013), every ex-post impact must be included in the analysis.

Likewise, the environmental consequences of removing mangroves are a cost associated with all scenarios. A number of further environmental costs are included in all scenarios — the removal of coastal plants, which provide natural coastal protection services, and the destruction of habitats during excavations. The cost of any further disruption of natural coastal processes is only expected under the Build New Seawall scenario, and, therefore, is not counted under any other scenario.

11 A 50-year period has been chosen because it is assumed to be long enough to capture all of the costs and benefits associated with the project while accepting that forecasts become more uncertain as the timeframe increases.

Table 6. Costs and benefits of adaptation options.

Impact	No further intervention	Relocate Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Direct relocation costs					
Clearing Site A	x	x	x	x	
Stabilising Site A	x	x	x	x	
Preparing Site B		x			
Preparing Site C			x		
Materials for building new houses		x	x	x	
Labour for building new houses					
Identifying new water source		x	x	x	
Constructing new water supply		x	x	x	
Direct seawall costs					
Engineering and design					x
Construction					x
Maintenance					x
Direct relocation benefits					
Avoided loss of subsistence production		x	x	x	x
Avoided loss of cash incomes		x	x	x	x
Avoided damage from coastal inundation		x	x	x	x
Avoided damage from extreme event		x	x	x	
Environmental costs					
Removal of mangroves	x	x	x	x	x
Removal of coastal plants	x	x	x	x	x
Destruction of habitats during land excavations	x	x	x	x	x
Disruption of natural coastal processes					x
Social costs					
Moving to smaller houses		x	x		
Loss of ease-of-access for older generation		x	x		
Government failure		x	x		

8. Measuring costs and benefits

Where possible, the costs and benefits listed above have been quantified monetarily. In some cases, quantification has not been pursued. For a detailed explanation of costs, refer to 'Appendix D: Quantified costs'. The costs and benefits that have not been quantified are outlined in Section 8.3.

8.1 Quantified costs

Table 7 lists the costs that have been quantified in this analysis. The cost of new housing materials is taken from plans for a 7.2 m x 4.8 m open space timber-framed house with a toilet, shower and laundry on the side, commissioned by the Rural Housing Unit of the Government of Fiji in 2016 (see 'Appendix E: Housing plan').

The costs of constructing a new seawall have been taken from the plans for a stone masonry seawall in a similar setting at Nasegai village on Kadavu Island. The cost of removing mangroves is based on valuations of "ecosystem services" of mangroves in Fiji estimated by Gonzalez et al. (2015). All other costs are based on those experienced during the relocation of Vunidogola Village on Vanua Levu, the second largest island in Fiji, in 2012. 'Appendix D: Quantified costs' provides a detailed description of the data sources, valuation methods, and issues associated with quantifying each cost.

Table 7. Quantified costs in 2015 Fijian dollars (FJD) and year of impact.

Impact	Cost (2015 FJD)	Year of impact
Direct relocation costs		
Clearing Site A	$208,565	2016
Stabilising Site A	$6,640	2016
Preparing Site B	$190,000	2016
Preparing Site C	$95,000	2016
Materials for one new house	$17, 147	2016
Labour for one new house	$2,781	2016
Verifying & constructing new water source	$70,645	2016
Direct seawall costs		
Construction	$688,394	2016
Maintenance	$34,420	Every project year
Environmental costs		
Removal of mangroves	$7,830	Every project year
Other costs		
Administration	$10,714	2016

8.2 Quantified benefits

The main impact of coastal inundation described by the community was the time devoted to and the resources spent on repairing damage caused by severe high tides. At present, only houses within the Red Zone face the effects of inundation (Mineral Resources Division 2013), and the majority of these impacts fall on the Red Zone only.

The household survey revealed that, on average, each house within the Red Zone devoted eight days per year to repairing damage caused by inundation. The first three benefits described in the following sections deal with this issue and have been valued using information gathered during the survey. The fourth quantified benefit is related to the community's vulnerability to disaster risks. Because the houses are to be built to appropriate standards, this benefit may be received by any household that is relocated, whether it is in the Red Zone or not.[12]
As explained in 'Section 4: Incorporating climate change', sea level rise is expected to increase the impacts of

12 The housing plans have been approved by the Fiji Institution of Engineers, however, the ability of timbre frame housing to withstand extreme weather is limited (PCRAFI 2011). The implications of this are explored in 'Section 10: Sensitivity analysis'.

inundation. It is, therefore, assumed that the number of days spent repairing damage will increase in line with sea level rise. To reflect this, the first three benefits described in the following sections increase by the same amount as the sea level is projected to rise year-on-year from 2016 until the final project year in 2066. Table 8 summarises the quantified benefits while the following sections provide the justification for and the valuation method of each category.

Table 8. Summary of quantified benefits in 2015 Fijian dollars.

Benefit	Area	Expected cost of damages (2016)	Unit
Avoided loss of subsistence production	Red Zone	$7,306	Per Red Zone per year
Avoided loss of cash incomes	Red Zone	$23	Per Red Zone household per day
Avoided damage from coastal inundation	Red Zone	$940	Per Red Zone household per year
Avoided damage from extreme event (1/50)	Entire village	$6,393	Per entire village per year

8.2.1 Avoided loss of subsistence agriculture production in Red Zone households

Every household in Narikoso relies on subsistence agriculture to provide a substantial portion of its food. The vast majority of fruit and vegetables eaten by the community is grown in gardens situated within the village boundaries. Chickens are reared in a poultry farm and their eggs are collected. Attending to household and community farms is a daily activity for the majority of men and women. Time spent away from farming is time spent away from cultivating the community's main food source. If the problems caused by inundation in the Red Zone did not exist — as they would not if the village was relocated or a seawall built — then each household in the Red Zone would not lose farming days. It is, therefore, important that this benefit be counted.

The value of the produce that each household grows for its own consumption is not normally calculated. The household questionnaire, therefore, asked respondents to list their household's average monthly consumption of food grown in the community's gardens. A typical 'subsistence diet' was then constructed using the most commonly grown foods and their quantities. To estimate the value of the subsistence diet of each household, the Suva Market price for each food type was then multiplied by quantity. This exercise resulted in a total value of FJD 42,067 per month for the entire village, or roughly FJD 61 per household per working day. The total avoided loss in the Red Zone — should it be relocated or protected by a sea wall — equates to FJD 7,306 in 2016 and increases from this base with sea level rise every project year thereafter.

8.2.2 Avoided loss of income in Red Zone households

Time spent repairing damage is time not spent earning a cash income. The main source of cash income in Narikoso is fishing. Village boats leave early each morning to fish the local reefs and their catch is sold to a community middle-man. The fish is then frozen and transported by ferry to Suva where it is sold at market. Some surplus fruit and vegetables are sold infrequently to local resorts. Interviews conducted by the CBA team revealed that this would be a more reliable source of income if the supply of fruit and vegetables could be more consistent. A more permanent revenue stream is received through the sale of eggs and chickens from the community chicken farm established by the SPC/USAID project 'Vegetation and land cover mapping and improving food security for building resilience to a changing climate in Pacific Island communities'.

Responses to the household questionnaire provided information as to the average weekly income of each household, including the income generated through the sale of fish and the more community-orientated activities mentioned above. The total monthly income reported for households in the Red Zone is FJD 8,971. On average, this corresponds to roughly FJD 23 per working day for each Red Zone household. This figure is also expected to increase with sea level rise every project year thereafter.

8.2.3 Avoided damage from inundation in Red Zone houses

In addition to the costs associated with the time spent carrying out repairs, there are direct costs incurred when repairing damages. Although materials will often be reused or repurposed, completely broken items must be replaced and some materials bought anew. The household questionnaire asked respondents whether they had incurred any such costs and how much had been spent.

In total, nine houses, all from the Red Zone, reported spending money on repairing or replacing damaged parts after previous inundation events. A common repair was the replacement of window louvres. One household had dismantled a kitchen positioned facing the sea and rebuilt it behind the house, as far away from the shoreline as possible. Of the nine households, FJD 940 was spent, on average, in the past year. Given the state of the inundation in Narikoso and expectations that it will increase in the future, it is assumed that all households in the Red Zone will face such costs. Therefore, the benefit of avoiding these costs should relocation take place or a seawall be built — equal to FJD 940 per household per year — is received by all 15 households in the Red Zone. This figure also increases in line with sea level rise.

8.2.4 Avoided damage from extreme events

Relocating households away from the shoreline reduces the risk of storm surges that cause damage during extreme events such as cyclones. If the newly built houses meet appropriate standards, the risk of damage caused by heavy winds is also reduced. The benefit of avoiding such damages is valued using the methodology outlined in 'Section 5: Incorporating disaster risk'.

To maintain consistency with the 50-year period of this analysis, the replacement costs estimated for a 1-in-50 year event in Narikoso have been used. This implies total avoided damages equal to FJD 321,582. This figure is then annualised to give a value of FJD 6,393 per year, for the entire 50-year period. The value of the avoided damage caused by an extreme event is, therefore, equal to FJD 6,393 per year. Unlike the other benefits valued in this analysis, this figure does not increase with climate change.

It should be noted that the mean return period used has been chosen somewhat arbitrarily. An extreme event of greater intensity than that associated with a 50-year return period may occur during the project timeframe. If, for example, a 1-in-70 year event struck Narikoso, the benefit of avoiding damages will be undervalued in this analysis. The effects of this uncertainty are explored in 'Section 10: Sensitivity analysis' where the results of the CBA are tested against the benefit of avoided damages associated with a 1-in-100 year event.

8.3 Unquantified impacts

Table 9 outlines those impacts that have been identified but have not been quantified monetarily. This means they are not included in the quantitative analysis of the costs and benefits given in 'Section 9: Results'. However, it may be the case that the unquantified impacts outweigh those that have been quantified and they should not be ignored. Each impact has been assigned an importance level according to how the CBA team perceived the impact would compare to the quantified impacts. If an impact has been assigned low importance, it is very unlikely to represent a significant impact. High importance suggests the impact may be significant relative to those that have been quantified. An assessment of the potential effect of these costs and benefits on the quantitative results of the CBA is given in 'Section 11: Discussion'.

Table 9. Unquantified impacts, an explanation and their potential importance.

Impact	Explanation	Potential importance
Unquantified costs		
Government failure to remove barriers to adaptation	One of the roles of government is to remove barriers to adaptive capacity. However, governments also face their own barriers which increase the chances that intervention will fail to improve adaptive capacity.	When resources are scarce and efficient adaptation requires the coordination of multiple ministries, government failure is a real risk. Adaptive capacity may not be improved or indeed made worse if the wrong intervention is selected. Importance: **High**.
Moving to smaller houses	The housing plans are for one room homes of 24' by 18'. The building survey revealed that many houses in Narikoso are substantially larger (see Appendix C) and some responses to the survey suggested that villagers would prefer to stay where they are.	If new housing is undesirable because it is too small then households will either reside in homes which provide them with lower utility or will remain in their original location. Importance: **High**.
Changing community dynamics	Relocating houses is likely to interfere with the present village set-up and may or may not have ramifications for customary governance structures that place emphasis on village lay-out etc.	The community has requested relocation through official processes but few consultations have focussed on potential disruption post-relocation. Importance: **High**.
Disruption of natural coastal processes	Seawalls are built to prevent further coastal erosion and flooding. They are frequently used where erosion will result in excessive damage to buildings or other infrastructure. However, they do not deal with the causes of erosion and, when designed poorly, disrupt natural processes when waves overtop the structure and through sediment scouring (Zhu et al. 2010).	Although a seawall may reduce the risk or erosion and flooding in the short term, the coastal zone remains high risk in the long term. Future developments of the coastal zone must take this into account and be planned carefully (Zhu et al. 2010). Importance: **High**.
Drainage system and electricity hook-ups	Not included in Project Design Document (Climate Change Division 2015). It is, therefore, assumed that the community will add onto existing infrastructure.	Rudimentary drainage system is unlikely to be expensive and no new electricity infrastructure is expected to be provided. Importance: **Medium.**
Loss of ease-of-access for older generations	Relocating the village to higher ground means moving people further away from the sea, which provides the only mode of transport away from the village. This is likely to be particularly felt by older generations.	Potential problems associated with access were discussed during focus groups and consultations held with the community but few respondents felt it would be an issue, perhaps because the distance will remain small. Importance: **Low.**

Unquantified benefits		
Less risk of migration to urban areas	Although largely undocumented, rural-urban migration has ramifications when urban centres are overcrowded and economic opportunities often limited. The associated risks have led Pacific based human rights organisations recommend reducing climate and disaster induced human mobility by building resilience in the place of origin (ProPa 2016).	Anecdotal evidence suggests that the ramifications of rural-urban migration such as those associated with family separation, land encroachment, informal settlements and unplanned urbanisation are increasing (ProPa 2016). Importance: **High**.
Removal of worry about the sea	Respondents to the community survey revealed that often parents worry about their children playing outside during extreme high tides.	The freedom from anxiety surrounding extreme high tides can only partially be achieved through relocation. Importance: **Medium**.
Better access to mobile phone signal	The new relocation site receives better mobile signal than the present village site. This is particularly important for contacting family outside of the village.	Good signal is difficult to find which could reduce communication options and have a significant impact on wellbeing. Importance: **Medium**.

9. Results

This section reports on the results of the quantification process, the CBA itself, and a comment on the distribution of the costs and benefits among the various actors. Because the impacts of each scenario are expected to accrue for many years after the project begins, costs and benefits that fall in future years have been discounted to enable a comparison in present value terms. Initially, a discount rate of 10% was applied to all monetised impacts that fall within the 50-year lifetime of the project. The discount rate has been chosen to remain consistent with other studies in the Pacific (Buncle et al. 2013). All figures are reported in 2015 Fijian dollars. The effect of selecting a different discount rate on the results of the analysis is explored in 'Section 10: Sensitivity Analysis'.

9.1 No Further Intervention — Baseline case

The costs and benefits of each intervention are measured against a scenario where no intervention takes place. Essentially, this represents a 'do nothing' approach where the community is left without government assistance. If this were the case — and the barriers to private adaptation remain in place — inundation would continue to impact on the Red Zone, disrupting subsistence and income earning activities. Materials would be required to repair damages and the community would remain at risk of the effects of an extreme event.

Table 10 details the results of the quantification of such impacts. The figures are presented as in the first year of the project (2016), a description of how the impact is expected to change in future project years (see 'Section 4: Incorporating climate change' for reasoning), and the present value of the costs over the timeframe assessed. The figures show that the impacts of not intervening — supposing the community could not access the resources to deal with coastal erosion itself — total roughly FJD 344,093 over the 50-year lifetime of the project in present value terms. These costs would be faced entirely by the community and provide an estimation of the monetary value of inundation in Narikoso. The effectiveness of each intervention is measured against this estimation.

Table 10. Quantified impacts of no intervention using a 10% discounted rate (costs in 2015 Fijian dollars).

Impact	Expected cost of damages (2016)	Future damages (2017–2066)	Cumulative present value of costs
Loss of subsistence production	$7,306	Increase yearly with sea level rise from 2016 base	$82,780
Loss of cash incomes	$2,805	Increase yearly with sea level rise from 2016 base	$31,783
Damage from coastal inundation	$14,100	Increase yearly with sea level rise from 2016 base	$159,751
Annualised replacement costs after extreme event (1/50)	$6,393	Constant	$69,778
		Total	$344,093

Further costs than the value of inundation exist under the baseline case. The impact of removing mangroves is counted under every relocation scenario (Buncle et al. 2013). The cost of clearing and stabilising Site A is included in all relocation scenarios. Table 11 indicates the additional costs already faced under the project in present value terms.

Table 11. Present value of costs of interventions already committed using a 10% discount rate (values in 2015 Fijian dollars).

Impact	Present value
Clearing Site A	$208,564
Stabilising Site A	$6,642
Removal of mangroves	$85,467
Total	$300,672

9.2 Costs of intervention

Table 12 displays the costs associated with each intervention relative to the base case where no further intervention takes place. The figures represent the total value of each impact over the lifetime of the project in present value terms. This means that all costs expected to be faced within each category from 2016 until 2066 have been monetised, discounted if they fall in any year beyond 2016, and summed together to equal the figure in the table.

A number of costs are identical across all scenarios. This includes those that have already been faced — clearing Site A, stabilising Site A, and removing mangroves — and those that will need to be paid for in any intervention — a new water supply and administration costs. The total value of costs that have already been committed is FJD 300,672. The total value of costs that must be faced in all scenarios is FJD 81,359.

Although many of the costs associated with each scenario are the same, some vary according to intervention. This is true of the value of the costs of preparing Site B and those associated with building houses. Given that it requires the clearance of the largest area of extra land and the greatest number of houses built, the Relocate Entire Village scenario entails the highest costs of the relocation scenarios. Perhaps inevitably because no more land clearance is required and it requires the fewest number of new houses, Relocate Front Line scenario entails the lowest costs, while Build New Seawall is the most costly of all scenarios.

Table 12. Present value of costs over the project's lifetime using a 10% discount rate (values in 2015 Fijian dollars).

Impact	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Direct relocation costs				
Materials to build new houses	$428,672	$257,203	$131,175	-
Labour to build new houses	$69,514	$41,708	$22,244	-
Clearing Site A	$208,564	$208,564	$208,564	-
Stabilising Site A	$6,642	$6,642	$6,642	-
Preparing Site B	$190,000	-	-	-
Preparing Site C	-	$95,000	-	-
New water supply	$70,645	$70,645	$70,645	-
Administration costs	$10,714	$10,714	$10,714	$10,714
Environmental costs				
Removal of mangroves	$85,467	$85,467	$85,467	$85,467
Building seawall				
Construction materials	-	-	-	$688,393
Maintenance	-	-	-	$341,264
Total costs	**$1,035,447**	**$755,081**	**$530,325**	**$1,125,838**

9.3 Benefits of intervention

The benefits of each intervention are given in Table 13. Unlike the costs of intervention, the benefits of intervention are not a function of the number of houses relocated. This is because inundation is only expected to impact on the Red Zone (Mineral Resources Division 2013) and, therefore, the benefits associated with inundation only accrue when households in the Red Zone are relocated or protected. For this reason, the value of the benefits associated with inundation of the scenarios Relocate Village and Relocate Red Zone are identical despite more houses being relocated under the former. The same is true of the Build New Seawall scenario, where the intervention protects the Red Zone from inundation despite no households being relocated. Under the Relocate Front Line scenario, some houses within the Red Zone would be left where they are so the value of benefits is lower.

As each new house should be built to the appropriate standards, the benefit of reducing the risk of damage due to an extreme event is proportional to the number of houses built. The value of the benefit is, therefore, greatest under the Relocate Entire Village scenario and lowest under the Relocate Front Line scenario. No benefits associated with disaster risk are received under Build New Seawall because the wall is not expected to meet the specifications required to protect the village from a storm surge.

As it encompasses both the full value of benefits associated with inundation and disaster risk, the scenario with the greatest benefits is Relocate Entire Village. The scenario Relocate Red Zone receives fewer benefits only because the number of houses protected from an extreme event is lower. The scenario Build New Seawall accrues a higher value of benefits than the Relocate Front Line scenario. This is because the value of inundation benefits in the Build New Seawall scenario outweighs the sum of inundation benefits and disaster risk reduction associated with relocating a small number of households from the Front Line.

Table 13. Present value of benefits over the project's lifetime using a 10% discount rate (values in 2015 Fijian dollars).

Impact	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Loss of subsistence production	$82,780	$82,780	$27,593	$82,780
Loss of cash incomes	$31,783	$31,783	$10,594	$31,783
Damage from coastal inundation	$159,71	$159,71	$53,250	$159,71
Annualised replacement costs after extreme event (1/50)	$69,778	$39,645	$21,931	-
Total benefits	$344,093	$313,960	$113,370	$274,315

9.4 Cost–benefit analysis

The quantified costs and benefits were aggregated to represent a single number or ratio so that each scenario may be compared easily. The net present value (NPV) and benefit–cost ratio (BCR) of each intervention have been estimated to allow a systematic comparison of the options.

Box 1. Interpreting net present value and benefit–cost ratio.

The net present value (NPV) of each scenario is calculated by deducting total discounted costs from total discounted benefits. If an intervention has an NPV of greater than zero, the benefits outweigh the costs and it is deemed to provide net economic benefits to society. If an intervention has an NPV of less than zero, the project results in net economic costs. The intervention with the highest, positive NPV would generally be considered the most beneficial to society. Interventions with negative NPVs provide negative net economic benefits compared to the baseline case where no intervention takes place.

An additional indicator useful in the decision making process is the benefit–cost ratio (BCR). The BCR provides an indication of the value of benefits received for each dollar faced in costs and is calculated by dividing total discounted benefits by total discounted costs. If an intervention has a BCR greater than one, more benefits are received than costs faced and society receives net economic benefits. If a BCR of less than one is registered, the opposite is true. The intervention with the highest BCR of greater than one is considered to be the most cost-effective of the options. Interventions with BCRs of less than one are not as cost-effective as the baseline.

In this study, potential interventions are analysed to ascertain whether they represent economically efficient solutions to the barriers to private adaptation in Narikoso. An economically efficient solution would have an NPV greater than zero and a BCR greater than one. The most efficient solution would achieve the highest NPV greater than zero and BCR greater than one. The solutions analysed are restricted to relocation and building a new seawall and therefore do not represent the full range of adaptation options. Further analysis would be required to ensure that the barriers to adaptive capacity are removed in the most efficient way possible.

In most instances, the option with the greatest NPV will also have the highest BCR. In cases where the NPV and BCR of each option rank differently, the decision maker may face difficulties in deciding which option is the most preferable. In general, the NPV is considered the principle decision criterion. The BCR is a useful alternative, but does not indicate the magnitude of net benefits as two projects with identical BCRs can have vastly different costs and benefits (Buncle et al. 2013). A good decision would recognise the attributes of both indicators.

Table 14 displays the total discounted costs, benefits, net present value (NPV) and benefit–cost ratio (BCR) calculated for each intervention. All four interventions studied result in negative NPVs and BCRs of less than one. This implies that the baseline case where no further intervention takes place is preferable to any proposed intervention. Based on the quantified values, the scenario with the least negative NPV is Relocate Front Line. This reflects the relatively low total costs associated with this option. The scenario with the highest BCR is Relocate Red Zone, implying that for each dollar faced in costs, 40 cents worth of benefits will be received. In comparison, for each dollar faced in costs by the Relocate Front Line, only 21 cents worth of benefits will be received. The rank of each option in each metric is given in brackets.

Table 14. Cost-benefit analysis results using a 10% discount rate (values in 2015 Fijian dollars).

Metric	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Costs	$1,070,217 (3)	$775,943 (2)	$541,451 (1)	$1,125,838 (4)
Benefits	$344,093 (1)	$313,960 (2)	$113,370 (4)	$274,315 (3)
NPV	**– $726,124 (3)**	**– $461,983 (2)**	**– $428,081 (1)**	**– $851,523 (4)**
BCR	0.32 (2)	0.40 (1)	0.21 (4)	0.24 (3)

Rank of each option in each metric in brackets

9.5 Distribution of costs and benefits

The comparison of costs and benefits presented above provides one measurement by which decisions can be made. A further consideration should be the project's distributional implications. As the project is presently designed, the financial costs associated with relocation are faced by the Government of Fiji and/or its development partners while the benefits mainly accrue to the community. This is important because the pursuit of relocation implicitly prevents the resources being utilised through alternative public projects in Narikoso or elsewhere in Fiji.

In this case, the costs of relocation appear to outweigh the benefits in aggregate, suggesting that relocation is not socially beneficial. Despite this, the community will receive the full value of the benefits without facing any financial burdens.[13] There may be grounds for accepting this disparity because Narikoso is a cash-poor community facing a problem to which the proposed solutions are far beyond its means. However, it could also be argued that the interventions represent inefficient solutions to the adaptive capacity constraints in Narikoso and that issues of equity should be addressed efficiently (Collier at al. 2008).

10. Sensitivity analysis

Many of the values used in any CBA are not known with certainty so assumptions were used to fill the gap. For instance, this CBA relies on a number of assumptions relating to the effect of climate change, the impacts of an extreme event and other technical details such as the relevant discount rate. Such assumptions have a direct impact on the results of the analysis. It is, therefore, important to explore known uncertainties within any CBA to identify whether the results remain robust to such inaccuracies. Sensitivity analysis is a simple method for testing the robustness of the results of the CBA to uncertainty.

13 The community would also face the environmental costs associated with the interventions and any social impacts.

10.1 Discount rate

With the exception of the removal of mangroves and the maintenance of the seawall, the costs of the scenarios fall almost entirely at the beginning of the project while the benefits accrue in the future. Bringing these future values into present value terms requires discounting. The choice of discount rate may have a large impact on results. This is because selecting a higher discount rate lowers the present value of, mainly in this case, the benefits of the CBA and, therefore, reduces the likelihood of producing a positive NPV.

The Government of Fiji does not presently endorse an official discount rate. Past studies concentrating on the Pacific commonly use discount rates between 7% and 10% (Buncle et al 2013), while the Asian Development Bank recommends using a discount rate between 10% and 12% for projects in the Pacific region (Zhuang et al. 2007). This CBA uses a central case discount rate of 10% while testing the results of the analysis against rates of 7% and 12%.

The NPV and BCR estimates for each intervention under different discount rates are presented in Table 15. Under a 12% discount rate, the NPVs and BCRs estimated become more unfavourable. This is to be expected because it is mainly the benefits that fall in the future and the higher discount rate reduces the value of those benefits in present terms. Under the lower discount rate of 7%, NPVs and BCRs still represent a negative economic payoff. This implies that the results of the analysis are robust to uncertainty surrounding the discount rate chosen.

Under the 10% discount rate, the scenario Relocate Front Line has the highest NPV (although still negative), closely followed by the Relocate Red Zone scenario. Under a 7% discount rate, Relocate Red Zone has the negative NPV closest to zero. This is because the magnitudes of the benefits associated with Relocate Red Zone are greater than Relocate Front Line, and this scenario is, therefore, more exposed to the impacts of a higher discount rate. Using a discount rate lower than 10% increases the present value of the benefits of Relocate Red Zone by more than under Relocate Front Line simply because the future values of the benefits of Relocate Red Zone are that much larger. Using a lower discount rate, therefore, changes the ranking of the options such that Relocate Red Zone offers both the highest NPV and BCR.

Table 15. Cost–benefit analysis results using discount rates of 7%, 10% and 12% (values in 2015 Fijian dollars).

Metric	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
7% discount rate				
NPV	– $629,771 (3)	– $376,358 (1)	– $416,772 (2)	– $913,766 (4)
BCR	0.43 (2)	0.53 (1)	0.27 (4)	0.29 (3)
10% discount rate				
NPV	– $726,124 (3)	– $461,983 (2)	– $428,081 (1)	– $851,523 (4)
BCR	0.32 (2)	0.40 (1)	0.21 (4)	0.24 (3)
12% discount rate				
NPV	– $765,553 (3)	– $496,966 (2)	– $432,622 (1)	– $825,231 (4)
BCR	0.28 (2)	0.35 (1)	0.18 (4)	0.22 (3)

Rank of each option in each metric in brackets.

10.2 Disaster risk

The benefits directly associated with reducing disaster risk may or may not occur depending on whether an extreme event occurs. Additionally, if an extreme event does strike, but is of greater or lesser intensity to that modelled in the CBA, the benefit may be overvalued or undervalued accordingly. The impact of this uncertainty on the results of the analysis can be tested by adjusting the mean return period of the associated replacement costs.

The central analysis uses annualised replacement costs associated with a 1-in-50 year event. If the only extreme event to hit Narikoso over the lifetime of the project was less intense, equivalent to 1-in-30 years say, then the benefit of moving households from harm's way would be overstated. If no extreme event strikes, then the benefit is overvalued even further. In either situation, the benefits of relocation will be lower than they are stated in the central case and, therefore, the NPV and BCR of each relocation option would represent negative payoffs of greater magnitude.

It may also be that Narikoso is unlucky and an extreme event of even greater intensity than 1-in-50 occurs. If this is the case then the benefits of relocation will be undervalued and the NPVs and BCRs presently calculated would underestimate the economic payoff of relocation. The effect of a more extreme event on the results of the analysis can be tested by inputting annualised replacement costs of an event of greater magnitude than 1-in-50.

Table 16 displays the replacement costs for a 1-in-100 year extreme event (the highest classification modelled by PCRAFI) annualised over the 50-year lifespan of the project and calculated using the methodology outlined in 'Section 5: Incorporating disaster risk'. For ease of comparison, replacement costs for a 1-in-50 year event are also replicated. The table shows that the benefit of relocating households away from the disaster risk does indeed increase if a 1-in-100 year cyclone were to strike. Table 16 also presents the results of the CBA calculated using the benefits associated with a 1-in-100 year event instead of a 1-in-50 year event. The NPVs of each relocation scenario remain negative. The BCRs of each scenario remain less than 1, implying that intervention is socially inefficient even if the most unlikely extreme event modelled is included in the analysis. The same is true when varying discount rates between 7% and 12%.

Table 16. Cost–benefit analysis results with 1-in-100 year replacement costs discounted at 10% (values in 2015 Fijian dollars).

	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Annualised replacement costs after extreme event (1-in-50)	$69,778	$39,645	$21,931	-
Annualised replacement costs after extreme event (1-in-100)	$115,491	$65,580	$36,298	-
Cost–benefit results				
Costs	$1,070,217 (3)	$775,943 (2)	$541,451 (1)	$1,125,838 (4)
Benefits	$389,806 (1)	$339,894 (2)	$127,737 (4)	$274,315 (3)
NPV	– $680,411 (3)	– $436,048 (2)	– $413,714 (1)	– $851,523 (4)
BCR	0.36 (2)	0.44 (1)	0.24 (3)	0.24 (3)

Rank of each option in each metric in brackets.

10.3 Climate change

The analysis has taken climate change into account by estimating the impact of sea level rise on the community. 'Section 4: Incorporating climate change' explains that there are large uncertainties involved with projecting climate change. This is also true for estimating the impacts of climatic changes.

It could be that sea level rise is greater than expected. This would increase the costs faced by the community should no further intervention take place, and therefore increase the benefits of intervention. If sea level rise is less than expected, the opposite is true. The efficiency of intervention would either be underestimated or overestimated accordingly.

In addition, the relationship between sea level rise and the damage caused by inundation is unknown. For the purposes of this CBA, it has been assumed that sea level rise and damage done are perfectly correlated. This means that the impacts of No Further Intervention increase by the same year-on-year percentage as sea level rise has been projected. However, if the relationship is not proportional, and a one percentage point sea level rise causes more or less than a one percentage point increase in damages, then the impacts of No Further Intervention are understated or overstated.

Table 17 presents the results of the analysis under sea level rise 10 times greater than that in the core analysis.[14] This represents an extreme climate scenario, or alternatively, a scenario where the relationship between sea level rise and damage done is 10-to-1. Because sea level rise impacts on the benefits of intervention, the costs remain the same while the benefits increase. All scenarios result in negative economic payoffs, confirming that the analysis is robust to much of the uncertainty surrounding climate change. The same is true when using discount rates of 7% and 12%.

Table 17. Cost–benefit analysis results under extreme climate impacts using a 10% discount rate (values in 2015 Fijian dollars).

	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Costs	$1,070,217 (3)	$775,943 (2)	$541,451 (1)	$1,125,838 (4)
Benefits	$476,543 (1)	$446,411 (2)	$157,520 (4)	$406,765 (3)
NPV	– $593,673 (3)	– $329,532 (1)	– $383,931 (2)	– $719,073 (4)
BCR	0.45 (2)	0.58 (1)	0.29 (4)	0.36 (3)

Rank of each option in each metric in brackets.

10.4 Housing quality

The housing plans were developed by the Rural Housing Unit of the Government of Fiji and have been approved by the Fiji Institution of Engineers (see 'Appendix E: Housing plan'). However, the ability of timber-framed housing to withstand extreme events is limited (PCRAFI 2011). This represents a key risk to the realisation of the benefits of relocation. If housing is provided that fails to provide adequate shelter during an extreme event, then the community will not benefit from protection. This would reduce the quantified value of relocation benefits calculated in the CBA, pushing the NPV of each relocation scenario further into the negative.

14 Although a 10:1 ratio seems highly unlikely, the relationship between sea level rise and damage in Narikoso is completely unknown and, therefore, an extreme example has been chosen.

A similar impact would arise if some households choose to remain in their old houses despite new homes being built (as discussed in Section 8.3). During consultations, some members of the community indicated this to be their preference. All houses within the Red Zone are expected to be impacted by inundation as time goes on, however only the Front Line of houses is presently impacted directly by inundation. The risk of households choosing to remain is, therefore, particularly important when relocating houses outside of the Front Line. However, if any relocated household remains, the benefits associated with disaster risk will not be realised in an extreme event. This results in greater negative economic payoffs for each relocation intervention.[15]

The implication of both points is that housing quality is important to the success of the project. If houses are not built to withstand extreme events, either because of design faults or poor building quality, the community will remain at risk of the impacts of a disaster. Moreover, the correct incentives need to be in place to ensure households do relocate should new homes be built for them. This means that the new housing must provide greater or equal utility than that which will exist just a few hundred metres away in the old village site.[16] Preferences for design and size must, therefore, be taken into account before housing plans are finalised. However, it must also be noted that tailoring housing designs to household requirements is likely to increase the costs of relocation substantially and, where the benefits of relocation are limited, result in lower economic payoffs than presently calculated.

10.5 Removing sunk costs

A further source of uncertainty exists through costs that have already been incurred. It is not clear how the decision to clearing Site A was made or what environmental and geotechnical assessments were carried out. However, the cleared land was left unstable and unsuitable for construction. In addition, the land is only capable of accommodating eight houses, a third of those it was intended to house.

It is true that land would need to be cleared under all scenarios. Nevertheless, the costs of clearance might have been optimised if environmental and geotechnical assessments had occurred first. The appropriate assessments would reveal issues such as which land is unstable and which land should be targeted. A full environmental impact assessment may have prevented mangroves being cut down unnecessarily to provide access for machinery.

To test the results of the relocation scenarios to these uncertainties, it is assumed that Sites B and C could be cleared for FJD 95,000 each, or half as much as the budget devoted to clearing the equivalent land (Site B + Site C) in the PDD. It is further assumed that, had it been optimised, the cost of clearing Site A could have been achieved for the same amount (FJD 95,000). The costs of stabilising Site A are removed altogether as are those associated with the removal of mangroves.

Table 18 presents the results of this analysis. Despite reducing the costs of intervention, all four scenarios continue to represent negative economic payoffs. This is true of all three relocation scenarios and that of Build New Seawall, which, despite no longer including the costs of removing mangroves, still represents the least preferable option. The same conclusions are true using discount rates of 7% and 12%.

15 Disaster risk reduction benefits are zero in the Build New Seawall scenario because the seawall is not expected to prevent the impacts of a storm surge.

16 The buildings survey revealed that many houses in Narikoso have multiple bedrooms and private washrooms, for example.

Table 18. Cost–benefit analysis results after removing sunk costs using a 10% discount rate (values in 2015 Fijian dollars).

	Relocate Entire Village	Relocate Red Zone	Relocate Front Line	Build New Seawall
Costs	$864,545 (3)	$570,271 (2)	$335,779 (1)	$1,125,838 (4)
Benefits	$344,093 (1)	$313,960 (2)	$113,370 (1)	$274,315 (3)
NPV	– $520,452 (3)	– $256,310 (2)	– $222,409 (1)	– $851,523 (4)
BCR	0.40 (2)	0.55 (1)	0.34 (3)	0.24 (4)

Rank of each option in each metric in brackets.

11. Discussion

This study has assessed whether relocation or building a new seawall represent economically efficient government interventions to remove the barriers to private adaptation in Narikoso. A wide range of impacts associated with hard adaptation options were taken into account. Based solely on the results of the quantitative analysis, the costs of each intervention analysed appear to outweigh the benefits by considerable amounts. On this evidence alone, neither relocation nor building a new seawall are efficient solutions to adaptive capacity constraints in Narikoso. In reality, the quantitative analysis does not reflect the full range of costs and benefits. Of the unquantified impacts identified, the more pressing represent costs. The most significant unquantified benefit is probably the reduction in the negative aspects of rural–urban migration (ProPa 2016). While further study would be required to provide a definitive conclusion, it would seem that the costs associated with changing community dynamics and government failure would outweigh this benefit. This suggests the interventions analysed would become more unfavourable should the unquantified impacts be included in the quantified analysis.

11.1 Implications for the Narikoso Relocation Project

Although relocation and building a new seawall do not represent efficient solutions, alternative government interventions in Narikoso may be justified as there are significant barriers to adaptive capacity preventing the community from acting alone. Given this, further study into alternative options is warranted and highly recommended. Soft adaptation measures include those that utilise natural capital, emphasise community control, simpleness and appropriateness (Sovacool 2011). Ecosystem-based approaches such as replanting mangroves have been shown to be socially beneficial in other parts of Fiji (Rao 2013), and the efficiency of their use in improving adaptive capacity in Narikoso should be explored.

Should a hard adaptation option be pursued by the Government of Fiji, it should, on balance, be Relocate Red Zone.[17] Compared with relocating the entire village, moving fewer houses than was initially planned for would open up opportunities for resources to be allocated towards other activities such as those that increase the economic resilience of the community. The proximity of Narikoso to nearby tourist resorts, plus the community's ability to farm, as revealed by high values of subsistence production, suggests that an as yet unexploited opportunity for enhancing living standards exists. The government could consider investing in routes of access to such markets for Narikoso's produce for example. If successful, such investments are likely to go at least some way towards removing impediments to adaptation caused by low cash incomes, which contribute to the first barrier to adaptive capacity highlighted in Section 2.2.2. It may also have the co-benefit of mitigating against the potential disruption cause by a partial relocation.

Taking a broader view, the analysis underscores the value of enacting the recommendations provided in previous

17 The NPV of Relocate Front Line is greater than that for Relocate Red Zone but only by a very small margin. On the other hand, Relocate Red Zone has by far the highest BCR. Given this combination, Relocate Red Zone appears to be the most favourable intervention analysed, albeit still a socially inefficient solution. Relocate Red Zone also has the highest NPV and BCR under the 7% discount rate and extreme climate change scenarios.

assessments (Mineral Resources Division 2013; Bosserelle et al. 2015b). Although unlikely to provide long-term adaptation solutions, the recommendations listed in Appendix A have been designed to maximise the chances of the beach returning as a coastal protection asset naturally. The recommendations in Bosserelle et al. 2015 are likely to be relatively low cost and could be performed by the community themselves if provided with the correct information. Disseminating information about how climate change may affect the community's vulnerabilities and simple measures to adapt to them would act to remove the information constraint described in Section 2.2.2.

11.2 Implications for national relocation guidelines

The results of the analysis are particular to past and future developments in Narikoso. Nevertheless, the constraints to adaptive capacity in Narikoso are likely to resemble those in many other low-lying coastal iTaukei communities. Consequently, the analysis offers lessons for the national relocation guidelines specific to iTaukei lands.

Perhaps the most obvious lesson is that relocation is a costly endeavour. It could be argued that the direct costs outlined for Narikoso are at the lower end of what is expected; inexpensive, identical housing designed without consideration of individual household need, no provision of electricity hook-ups or drainage, and no investment in livelihood activities. Despite this, the costs associated with relocation in Narikoso are substantial and far outweigh the quantified benefits of doing so. It is unlikely that affected communities will be able to meet such costs alone and at least part of the burden of future direct relocation costs may fall to the government.

Although unquantified in this analysis, there are important indirect costs of relocation that are likely to be imposed on communities. These include the disruption of current community norms and the risk of government failure (see Section 8.3). The negative impact this may have on adaptive capacity in already vulnerable communities should not be ignored. To ameliorate this risk, and ensure adaptive capacity is strengthened, allowances must be made for post-relocation investment in livelihoods. Although this study has characterised some negative impacts, further study is required to ascertain their true extent and magnitude.

On the other hand, the benefits of relocation depend almost entirely on the level of risk faced by the community. In Narikoso, the initial decision to relocate the whole community was made independently of assessments of vulnerability, which now suggest it is only the Red Zone that is at risk from inundation. There may be good reasons for choosing to move entire communities rather than just the most vulnerable households.[18] However, relocation need not only beneficially occur this way. It may be possible to move only the most vulnerable households without detriment to the community. In other words, there is no increase in the magnitude of relocation benefits achieved by relocating the vulnerable households plus everybody else. This results in identical benefits to relocating vulnerable households only.

Given the above, the Government of Fiji may wish to consider the following six points when finalising the national relocation guidelines.

1. **Community-specific risks must first be identified, assessed and understood properly through the application of geotechnical, coastal oceanography, environmental and social impact assessments.** This will require synchronising local knowledge with expertise in the sciences, land affairs and rural development. The CCD has made progress towards achieving this through the multi-ministry Relocation Taskforce. It should now pursue a mandate for the Taskforce through the appropriate channels. This is likely to take the form of approval from Cabinet through the drafting of a Cabinet Paper.

18 Such reasons may be compounded when the distance between the 'old' and 'new' village sites is large. However, it is assumed that the majority of relocations on iTaukei land will be short in distance, much like in Narikoso.

2. **To ensure that government intervention is justified, barriers to private adaptation should be identified and solutions designed to remove them.** Unpacking the constraints to households' capacity to privately adapt should be the first level of government intervention in the relocation guidelines. Focussing on barriers to private adaptation is likely to broaden the range of potential public solutions to climate risks beyond relocation. Where intervention is justified, hard and soft options should be studied and their efficiency at removing barriers determined.
3. **Once risks and adaptive capacity have been assessed, government assistance may be targeted to the most vulnerable communities and only when relocation represents the most efficient solution.** The high cost of relocation means that the government must make choices about where to devote resources. Resources should, therefore, be directed toward communities that face the highest levels of risk and, even then, relocation should only be pursued when all other options for removing the impediments to private adaptation have been exhausted. The methodology used to rank vulnerable communities should be decided on by the Relocation Taskforce.
4. **There may be situations where vulnerability could be reduced to acceptable levels without relocating the entire community.** The national guidelines should make provisions for the possibility of partial relocations, particularly in areas where the distance between new and old village sites is small and the risks are faced by a relatively low number of households. Given the intangible costs of relocation, this could be less disruptive than relocating entire villages.
5. **The adverse consequences of relocation are important and should be considered throughout the relocation process.** Disruptions to community dynamics and the risk of government failure represent potentially significant costs. Provisions for mitigating such impacts should be considered from the moment a need to relocate is brought to the attention of the relevant authority. This could be done through investments in livelihood activities that exploit community-specific strengths.
6. **The government should seek partnerships with organisations already working in related activities.** The sheer scale of the issue coupled with a lack of resources suggests that the Relocation Taskforce would likely benefit from the increased capacity provided by non-governmental organisations and other development partners with useful expertise.[19] Bringing together multiple stakeholders from within government and outside of it may provide efficiency savings and reduce the risk of government failure.

19 The cost-benefit analysis team benefited from discussions with Habitat for Humanity – Fiji during the completion of this work. Habitat for Humanity has significant experience in building new homes in vulnerable communities throughout Fiji, and the government may wish to investigate a partnership.

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Appendix A: Evidence of coastal erosion and proposed solutions

Analysis performed by oceanographers from the Geoscience Division of the Pacific Community on behalf of the Mineral Resources Division (MRD) of the Government of Fiji confirms the existence of coastal erosion at Narikoso Village in Fiji (Bosserelle et al. 2015b).

The study found the beach to be naturally stable with a sediment supply capable of providing valuable and dynamic coastal protection. However, the current seawall was highlighted as a likely determinant of erosion that is presently threatening households. The removal of mangroves and attempts to protect the beach by placing large boulders along the backshore was found to have further contributed to unnatural sediment loss. The report recommends a number of measures that, if enacted, would maximise the natural coastal protection services provided by the beach, including:

- breaking up and removing the old seawall to prevent unnatural sediment loss;
- continuing efforts to replant mangroves, which will act to block waves and prevent sediment from being taken offshore during storms;
- removing boulders from the beach, which were placed there to protect the shoreline but are likely contributing to sediment loss during very high water levels by forming storm scour holes, and;
- creating a buffer zone between the village and the shoreline where no buildings are allowed to be established.

The above measures could enable the beach to move more naturally, roll back better with rising sea levels, better absorb energy during storms and, ultimately, provide some protection from coastal inundation.

Appendix B: Photos of Narikoso

Photo B1. Front Line household at high tide. The householder believes that the thick crack to the left is caused by the house sinking due to inundation. (Photo: James Jolliffe)

Photo B2. Breached seawall at high tide (Photo: James Jolliffe)

Photo B3. Breached seawall at high tide (Photo: James Jolliffe)

Photo B4. Extent of damage to seawall at low tide (Photo: James Jolliffe)

Appendix C: Estimating avoided damage from a disaster

To measure exposure to disaster risks, the Pacific Catastrophe Risk and Financing Initiative (PCRAFI) has constructed a database of 3.5 million residential, commercial, public and industrial buildings in 15 Pacific Island countries (PacRIS database). The database includes — among many variables — locations, number of storeys, structural characteristics, and the costs of replacing each building should it be destroyed.[20] The expected damages caused by future extreme events are estimated using functions of damage vulnerability and extremity of event. For example, for a particular damage function, a 100 mph wind may be expected to cause damages requiring repairs of up to 20% of the total replacement cost of a building. Figure C1 displays the process by which PCRAFI assesses risk. For more information on the methods adopted by PCRAFI, please refer to the PCRAFI Risk Assessment Methodology (2011).

Although the data collected and modelled by PCRAFI in Fiji is extensive, none exists specifically for Narikoso. However, PCRAFI's Pacific Risk Information System (PacRIS) database contains data on 1,082 building complexes — one complex may contain multiple buildings — throughout other parts of Kadavu Province. The cost–benefit analysis (CBA) team, therefore, conducted a survey of the buildings in Narikoso and used it as the basis for several manipulations of PacRIS data that exists for Kadavu. The value of damage caused by potential tropical cyclones was estimated by loosely following the PCRAFI Risk Assessment Methodology depicted in Figure C1. The following sections describe this process.

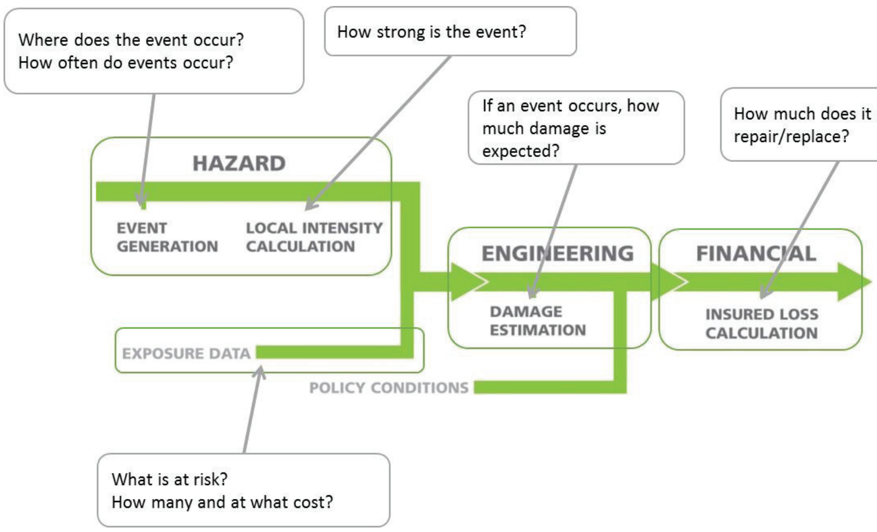

Figure C1. Pacific Catastrophe Risk and Financing Initiative risk assessment methodology. Source: AIR Worldwide

Buildings survey

Exposure was estimated by collecting data on building characteristics. Table C1 reveals the characteristics that were surveyed by the CBA team and each category of characteristic found in Narikoso. The variables were chosen because of their ease to collect by an inexperienced surveyor and their relative importance in determining replacement costs.

20 The project also modelled the disaster risk to infrastructure and crops, but these are not relevant to the immediate objective of this study.

Table C1. Narikoso building survey variables.

Characteristic	Categories	Survey method
Building location	Latitude and longitude of each building	Coordinates taken from Google Earth
Construction type	Single storey timber frame Single storey masonry/concrete Single storey combination masonry/concrete and timber frame	Visual inspection
Occupancy class	Residential - Permanent dwelling single family Commercial - General commercial Public - Education Public - General public facility Public – Religion Infrastructure	Household survey
Floor area	Total area in square meters of each building	Calculated using Google Earth Pro

Figure C2 is a satellite image of Narikoso with each building indicated by a yellow or red box. The latitude and longitude of the buildings were taken from Google Earth by highlighting the household and noting down the coordinates. Construction type was detailed through visual inspection by the CBA team during a visit to Narikoso. Questions posed during the household survey revealed occupancy class. Finally, the floor area of each building was approximated using the polygon area measurement tool in Google Earth Pro.

To illustrate how this was done, consider the red box in Figure C2. Google Earth Pro estimates that the property lies 5 m above mean sea level at the coordinates 18°55'03.79" S and 178°30'25.45" E. Visual inspection of the building revealed that it is one storey high and is constructed using a combination of masonry, concrete and timber frame. The occupants of the household informed the survey team that the building is residential and occupied by a single family. The red polygon depicted in Figure C2 was drawn on Google Earth Pro and has an area of 51.5 m, suggesting the building has a floor area of 51.5 m. The same process was carried out for each building. Table C2 outlines the results of this exercise for the entire village.

Figure C2. Google Earth Pro image of building footprints in Narikoso and picture of one household taken during visit.

Table C2. Number and floor area of buildings in Narikoso by occupancy and construction type.

	Timber frame		Masonry		Combination	
	Number	Floor area	Number	Floor area	Number	Floor area
Residential - permanent dwelling single family	22	1453	5	533	3	481
Commercial - general commercial	1	53	-	-	-	-
Public - education	1	74	-	-	-	-
Public - general public facility	1	113	-	-	-	-
Public - religion	1	105	1	161	-	-
Infrastructure	1	24	-	-	-	-
Total	27	1822	6	694	3	481

Replacement costs

The total replacement value for each building was estimated using data from the PacRis Kadavu dataset. The replacement value per square meter of floor space was calculated for buildings with the same occupancy and construction type in the PacRIS Kadavu dataset. This value was then multiplied by the floor area of each respective building type in Narikoso to give replacement costs for residential housing — should it be completely destroyed — including transportation of materials.

Although Tropical Cyclone Winston in February 2016 displayed the potential destruction an extreme event can cause in Fiji,[21] a cyclone powerful enough to destroy every building in Narikoso is an unlikely occurrence. There is a relationship between the intensity of a cyclone and the damage it may be expected to cause (in addition to the likelihood of an event occurring). Different types of buildings may suffer different levels of damage according to the materials they are constructed with; a standard concrete house would probably fare better during cyclone winds than a standard wooden house, for example. The next step is to estimate the level of damage — measured as a percentage of total replacement costs — that would occur in the event of a tropical cyclone in Narikoso.

Damage functions

The relationship between the intensity of a tropical cyclone and the associated expected loss is made available via the PCRAFI Damage Tool.[22] The Damage Tool provides estimations of the damage ratio of different building types according to wind speed. For example, the Damage Tool suggests a single storey timber frame building subjected to a cyclone generating winds of 100mph will experience damages equivalent to 9.6% of its total replacement value. An identical building facing a 200 mph cyclone will experience damages of 100% of its total replacement value. Multiplying the damage ratios for each building type for wind speeds between 40 and 200 mph by total replacement values in Narikoso allows local damage curves to be calculated.

The damage curves indicate the greatest losses, across all wind speeds, can be expected from timber frame buildings. If, for example, a cyclone of 150 mph were to strike Narikoso (within the range of Tropical Cyclone Category 4), then expected damages would total 86.8% of timber frame houses, 58.0% of masonry houses, and 66.6% of buildings built using a combination of materials.

21 Kadavu is situated well away from the path of Cyclone Winston, out of range of the most destructive winds. Narikoso was largely unaffected by the cyclone as a result.

22 The impact of storm surge is factored into the damage ratios provided by the Damage Tool, however the extent to which damage is caused by wind as opposed to by storm surges is not made publicly available. An interested party may wish to consult Air Worldwide to inquire.

PCRAFI risk curves

PCRAFI used records of the occurrence and severity of past events to simulate potential future events. In total, 10,000 potential futures were simulated across the Pacific using mathematical models. In combination with the damage ratios outlined above, the simulations allow for estimations of the likelihood of damages occurring according to the potential location and intensity of an event. For example, the expected damage caused by a 1-in-50 year event — which translates as having a 2% chance of occurring each year for the next 50 years — may be valued. The risk profile for Kadavu calculated through PCRAFI, converted to 2015 Fijian dollars, is shown in Figure C4.[23]

The information displayed in Figure C4 can be interpreted in a number of ways. For example, the chart shows that Kadavu is expected to observe an annual buildings loss due to cyclones of over FJD 19,000,000, on average, every 100 years. This implies that there is a 1% chance of Kadavu experiencing losses of FJD 19,000,000 for any given year. Following similar logic and reading from the chart, losses of FJD 2,000,000 may be expected collectively every 10 years, or there is a 10% chance of losses of FJD 2,000,000 occurring in any given year. Importantly for this CBA, risk curves allow for approximations of the value of the damage caused by an extreme event according to the likelihood of an event occurring.

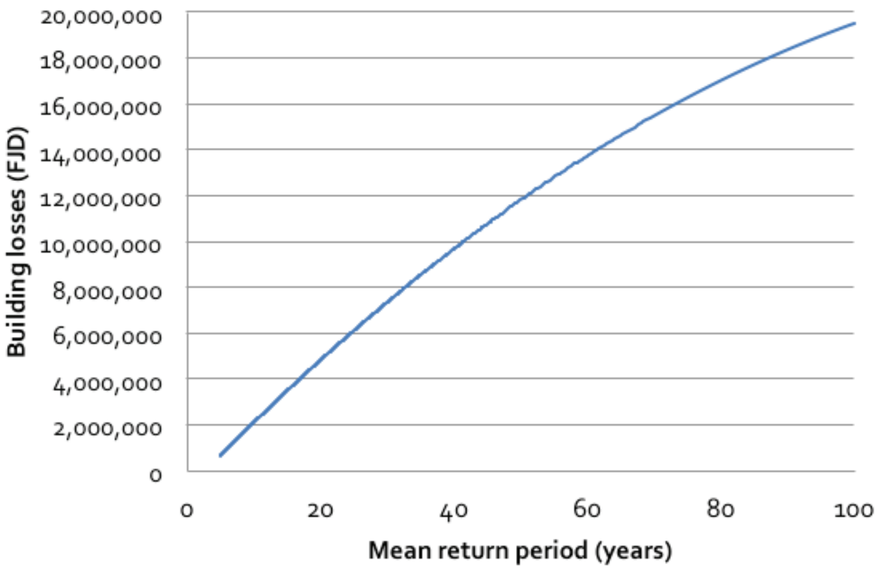

Figure C4. Building loss risk profile for Kadavu Island. Source: Pacific Catastrophe Risk and Financing Initiative

The PCRAFI calculations were performed through a risk module owned and operated by AIR Worldwide, a US company that provides risk modelling and consulting services. The risk module is not available for public use and, therefore, cannot be used to calculate a risk curve for Narikoso. However, the results of the risk model developed by AIR Worldwide for Kadavu Province are available for download from PCRAFI. These results have been used to provide a rough calculation of a risk curve for Narikoso.

23 The curve shown in Figure C4 is smoothed using the polynomial trend line function in Microsoft Excel. Although not a true depiction of the raw data provided by Pacific Catastrophe Risk and Financing Initiative, the smooth curve allows for clearer analysis of the underlying trend. The trend line has an R^2 value of 0.999, implying a very close fit.

Narikoso risk curve

A risk curve for Narikoso was calculated in the following way. First, the ratio of 1-in-100 year event Kadavu building replacement costs to total building replacement costs in Kadavu was calculated. The same ratio (0.085) was then applied to the total replacement costs calculated for Narikoso to give an approximation of 1-in-100 year event replacement costs in Narikoso. Second, the ratio between Kadavu 1-in-100 year event replacement costs and Narikoso 1-in-100 year event costs was calculated (0.03). This second ratio was then applied to each value from the Kadavu profile to estimate values for Narikoso across the entire risk curve, from a mean return period of zero to 100. The resulting risk profile for building loss in Narikoso is given in Figure C5.

Figure C5 shows that losses of just over FJD 450,000 are expected to be exceeded in Narikoso, on average, once every 100 years. Alternatively, the losses associated with a 1-in-50 year event are expected to be around FJD 300,000. Or, in other words, there is a 2% chance that Narikoso will experience building damages equal to around $300,000 in any given year.

The risk curve depicted in Figure C5 indicates the potential value of the damage caused by a disaster in Narikoso and has been relied on to value the benefits of relocation. However, the risk profile has been created using a number of wildly inaccurate assumptions, including, but not limited to, an identical relationship between risk and replacement costs in Narikoso and the areas of Kadavu modelled through PCRAFI. A multitude of complexities exist, which means this almost certainly would not be true in reality. But in the absence of accurate risk modelling for Narikoso, this method provides at least a basic approximation of the community's exposure to disaster risk.

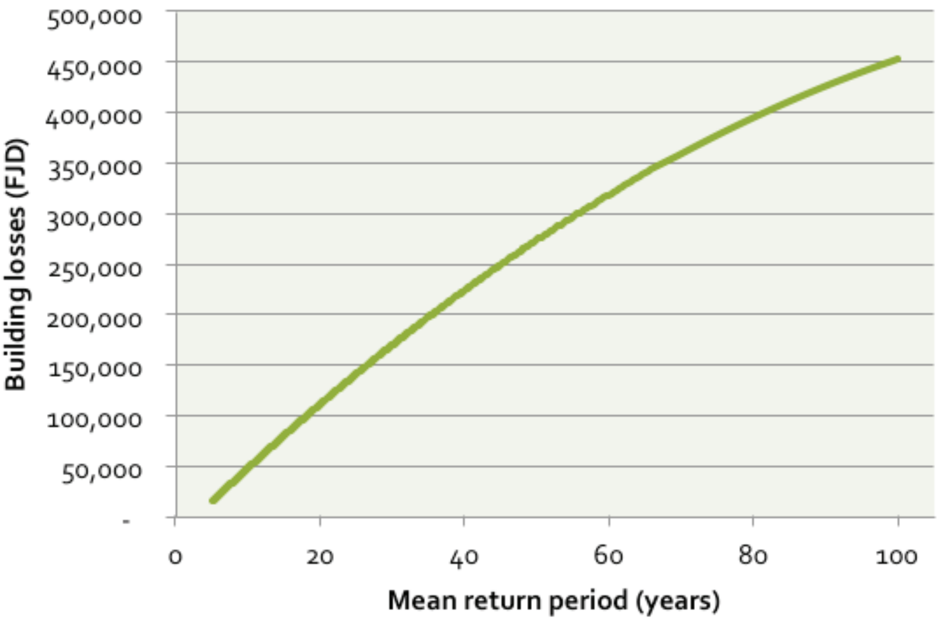

Figure C5 Estimated building loss risk profile for Narikoso (valued in 2015 Fijian dollars).

Appendix D: Quantified costs

Clearing Site A

This refers to the land cleared in Narikoso by the Royal Fiji Military Forces (RFMF) in 2012. The budget devoted by the Office for the Prime Minister is reported to be FJD 200,000 but there is no suitable reference available for this figure. It is not clear whether the entire budget was spent or exceeded, or whether all costs of excavating the land were covered. For the purposes of this cost–benefit analysis (CBA), it is assumed that all direct costs associated with the land excavations — including six months of labour, materials, fuel, transport, and other expenses – cost FJD 208,565.

Stabilising Site A

After the excavation of Site A, assessments carried out by the Mineral Resources Division (MRD) of the Government of Fiji suggested the land was settling but required some extra stabilisation work (SPC Trip Report 2013). Technicians from the Land Resources Division (LRD) of the Pacific Community (SPC) were mobilised to plant crops to stabilise the new site. 1,000+ vertiver grasses, 2,000 pineapple tops, and 80 tree seedlings of different species were planted on the sides of the excavated land. Further assessments have suggested the planting managed to stabilise the land successfully (SPC Trip Report 2014).

The pineapple tops, tree seedlings and vertiver grasses were transported from Suva to Kadavu by ferry and planted during two trips conducted by two members of LRD staff. All other known costs, including fuel (to collect vertiver grasses on two separate occasions) and administrative (to employ five men to do so) are included in the estimation. The direct costs associated with stabilising the land total FJD 6,641.84, as estimated from SPC reports. It should be noted that the total is undervalued because it does not include wages paid to SPC staff, nor does it consider indirect impacts such as environmental costs.

Preparing Sites B and C

Assessments carried out by MRD have concluded that the new, excavated village site is not large enough to accommodate every household. Taking into account both the area and stability of each section of land, Site A has capacity for eight households, which is equal to the number presently situated on the Front Line. Therefore, preparing Site B is unnecessary for the scenario where only the Front Line is relocated. However, for Relocating Entire Village and Relocating Red Zone, more houses will be required and further land will need to be cleared. The villagers of Narikoso have agreed on the boundaries of Site B and have pursued demarcation through the relevant authority — the iTaukei Affairs board of the Government of Fiji. The land lies above and adjacent to Site A. It is assumed that Site B is large enough to accommodate the remaining 17 households that do not fit within Site A.

If only the Red Zone were to be relocated, only seven additional houses would be required. For the purposes of this scenario, it is assumed that some of the demarcated land could be left as it is, while a smaller section is cleared. Should a decision be made to relocate the Red Zone only, the smaller section of land necessary has been labelled Site C.

No comprehensive analysis of the costs of preparing the land has been completed. However, the Climate Change Division of the government has estimated the cost of clearing, compacting and trimming Site B to be FJD 190,000 (Climate Change Division 2015). This does not include the costs of labour or transportation and should, therefore, be considered an underestimation. For the purposes of this CBA, it is assumed that the cost of clearing Site C is equal to half the cost of clearing Site B. Therefore, preparing Site B is given a value of FJD 190,000 and preparing Site C is given a value of FJD 95,000.

Removal of mangroves

To make way for the clearing of Site A in 2012, an area of mangroves at the northern end of the beach was removed (Bosserelle et al. 2015b). Mangroves provide a valuable coastal protection asset because they block waves and prevent sediment from being transported away from the shoreline during storms. The value of the ecosystem services provided by mangroves in Fiji has been estimated — taking into account the value of tourism attracted by them and their role in sequestering carbon — at FJD 9,788 per hectare per year (Gonzalez et al. 2015). This value has been used to estimate the impact of removing the mangroves.

The extent of the clearance is not clear, making it difficult to estimate the area of mangroves removed. For the purposes of this CBA, it is assumed that mangroves from a small portion (0.8 ha) of the beach front below Site A were destroyed. This results in a cost of FJD 7,830 per year, every year between 2016 and 2066.

Building materials for new houses

The new houses are to be built to the same plans developed in 2016 by the Ministry of Economy's Rural Housing Unit. The basic house consists of a 24' x 16' timber framed dwelling with toilet, shower and laundry built to the rear. The roof is to be made of galvanised corrugated iron and the exterior walls weatherboarded. The cost of all materials required to build one complete house is FJD 17,147 in 2015 dollars.

Labour for construction of new houses

Because the plans for new houses in Narikoso are similar to those built in Vunidogoloa, it is assumed that the cost of providing labour to build them is also similar. The labour costs budgeted for Vunidogoloa, inflated to 2015 FJD, equal FJD 2,780.54 per house. It is assumed — but is not a certainty — that labour did not fall over budget and this figure represents the entire cost of providing labour, including transportation of workers, meal allowances and any other expenses.

Verifying new water source and constructing new bore hole

The system presently supplying water to Narikoso relies on a surface water spring dam which has a tendency for weak flows and does not cater for times of high demand (Mineral Resources Department 2013). When the CBA team visited, water to community taps was being rationed to half an hour in the morning and half an hour in the evening. Taps within individual households were not supplied at all. Given the lack of a reliable supply to the village where it stands, a substantial new water source needs to be developed to feed the relocated households. The MRD have identified a suitable site for a new bore hole that will provide the new village site with ample water.

The Project Design Document dedicates a budget of FJD 4,500 for the verification of a new water source and the construction of a bore hole (Climate Change Division 2015). However, there are significant complexities associated with the development of a new water supply and, therefore, this CBA assumes the costs will be greater than those currently budgeted for. During the relocation of Vunidogoloa, the Water Authority of Fiji contributed FJD 70,645 for the construction of a similar supply system. This includes the costs of installing a reservoir and laying pipes to 30 households. The costs of developing a new water source in Narikoso are assumed to be the same as those in Vunidogoloa.

Constructing a new seawall

The costs of constructing a new seawall have been taken from the plans for a stone masonry seawall in a similar setting at Nasegai village on Kadavu Island. The proposed seawall is 295 m long and has a vertical height from current mean sea level of 1.5 m. The estimated cost for the construction materials with taxes removed, and including a 10% contingency, is FJD 688,394. This figure does not include the costs of land works, engineering or labour. These are likely to represent significant costs but are not known and are therefore excluded from the CBA. Measured using Google Earth Pro, the breached sea wall at Narikoso is 155 metres in length. For the purposes of this CBA, it is assumed that 155 m is sufficient and that a wall with the same dimensions as that proposed in Nasegai is applicable in Narikoso. In the absence of the proper technical assessments, this is no certainty.

Maintaining a new seawall

To ensure the effectiveness of the seawall, it must be monitored regularly and maintained so that deterioration does not occur. If the seawall is damaged even slightly then coastal erosion is likely and inundation becomes a threat once again. No suitable reference exists for the effective maintenance costs of seawalls in rural Fiji. For the purpose of this CBA, it is assumed that from the year after the wall is built, maintenance costs are equal to 5% of construction costs. This is assumed to include the costs of monitoring the seawall and resources devoted to maintenance. This equates to FJD 34,420 per year from Year 2 onwards.

Administration costs

A project of this scale is likely to entail significant administration costs. These are the day-to-day expenses faced by the organisations that work on the project. It is assumed that the administrative costs of the Narikoso Relocation Project are identical to those faced during the relocation of Vunidogoloa, inflated to 2015 Fijian dollars: FJD 10,714. It is further assumed that administrative costs remain identical across all proposed scenarios.

Appendix E: Housing plan