COST BENEFIT ANALYSIS OF COASTAL ZONE MANAGEMENT IN KOSRAE

SPREP
Secretariat of the Pacific Regional Environment Programme

The **Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR)** is a regional program which aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes (i.e. 'climate change and disaster risk mainstreaming').

The PPCR-PR is implemented by the Secretariat of the Pacific Regional Environment Program (SPREP) and Asian Development Bank (ADB) and is funded through the Climate Investment Funds (CIF).

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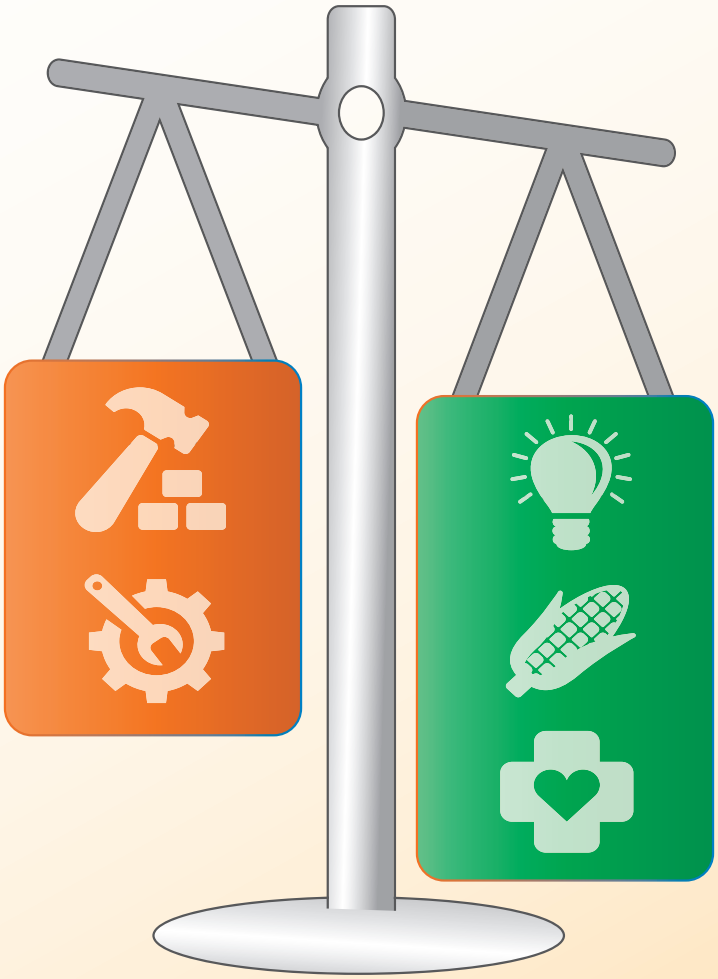
COST-BENEFIT ANALYSIS OF COASTAL ZONE MANAGEMENT IN KOSRAE (FSM)

ECONOMIC ASSESSMENT OF COASTAL ROAD RELOCATION IN THE FACE OF CLIMATE CHANGE



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Acronyms

CBA Cost-benefit analysis

FSM Federated States of Micronesia

KIRMA Kosrae Island Resource Management Authority

NIWA National Institute of Water and Atmospheric Research

PPCR Pilot Programme for Climate Resilience: Pacific Regional Track

SPC Pacific Community

DREA Department of Resources and Economic Affairs

Glossary

Storm berm: nearly horizontal or landward-sloping portion of a beach formed by the deposition of sediment by storm waves

Revetment: retaining wall, barricade or facing of masonry, earth, sandbags, or other material, to support or protect

Executive Summary

Background

Much community and infrastructure development in Kosrae over the last few decades has occurred within the coastal margins. However, much of the area in which this coastal development has occurred is susceptible to coastal hazards, such as long-term coastal change and episodic coastal inundation. The effects of climate change and, in particular, sea level rise are likely to exacerbate the threat of inundation to coastal developments and loss of infrastructure such as sections of the road network.

The areas most vulnerable to coastal inundation include the coastal area between Malem and Utwe (Figure 1). The community, road, and infrastructure in the area face numerous inundation events, with coastal homes in Malem and Utwe (98 houses plus businesses and amenities) exposed to regular over-wash. The effects of this over-wash include flooding of homes, damage to vehicles, and blockages/breaching of the road, cutting off villagers from homes, work, and access to amenities.

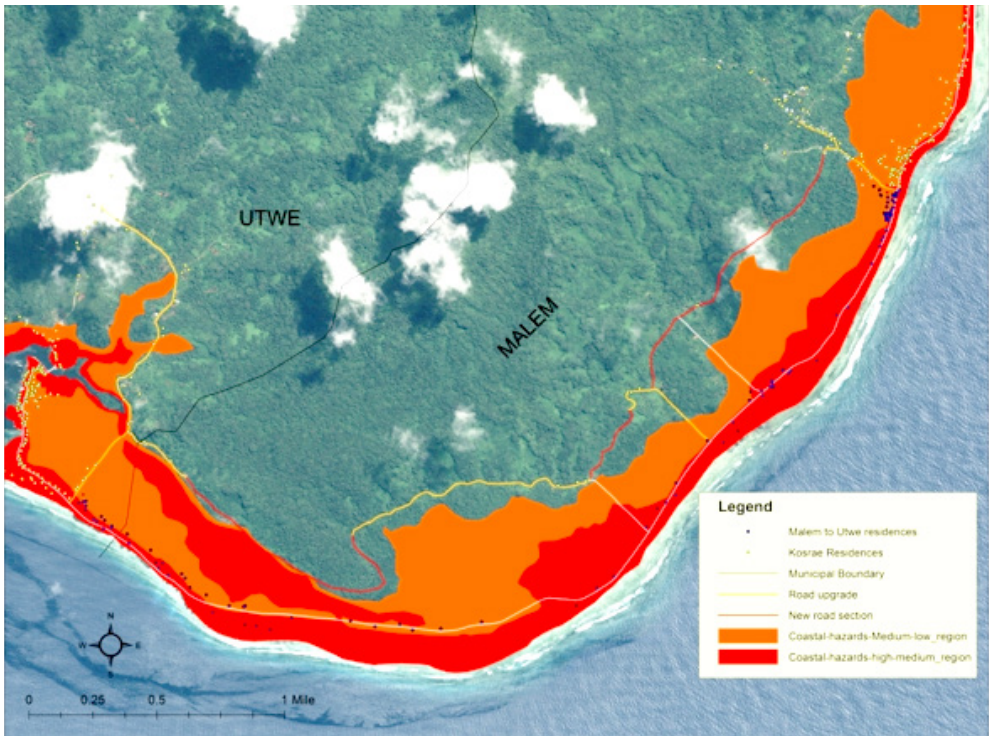


FIGURE 1. AREAS AT RISK OF INUNDATION. SOURCE: KIRMA (UNPUBLISHED)

The SPREP-executed Pilot Programme for Climate Resilience: Pacific Regional Track (PPCR-PR) aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes. In light of the coastal threats being faced along the Malem to Utwe coastal corridor, the State Government of Kosrae, in tandem with SPREP and the PPCR-PR, is developing a proposal to establish an interior road that links Malem to Utwe, by-passing the need for citizens to rely on the existing 4.5 kilometre coastal road for access while ensuring the safety of people in the coastal area. A secondary but important objective in the road project is to protect the long-term wellbeing of the Kosrae community by facilitating the relocation of families by opening up the interior.

Cost benefit analysis

In support of proposal development, an economic assessment of the benefits and costs of the road project has been undertaken. The relocation option has been compared against a series of alternative adaptation options, including coastal protection with revetment and upgrading the coastal road. In reality, the form that these options and an inland road could take can vary. For example, revetment could cover the entire coastline or just parts; new coastal roads could be built to existing design standards or to new design standards. This analysis assesses selected forms of the adaptation options to consider a way forward for Kosrae:

- establishing a protective rampart (revetment) to protect the affected coastline, in accompaniment of a new coastal road built to existing specifications;
- upgrading the coastal road (including elevating it) while revetting segments of the existing road that are particularly vulnerable to erosion;
- establishing an inland road while maintaining the existing coastal road for various lengths of time and revetting segments of it that are particularly vulnerable to erosion;
- establishing an inland road at various points in the future instead of today; and
- establishing just part of an inland road.

Data for this exercise were sourced principally from direct consultations with government departments and supplemented by expert opinion from National Institute of Water and Atmospheric Research (NIWA) and the Pacific Community (SPC). Estimates of the value of the different adaptation options in Kosrae were based on expert opinion of the effect that the options would have on costs faced by the Kosrean community from present over-wash trends (impacts of road, houses, earnings, and so on). The fact that data were not generated for all impacts means that the quantified benefits of adaptation options were underestimated.

Results

The analysis provides conservative estimates of the potential payoffs from the adaptation options because:

- the analysis is based on the quantified benefits from the different adaptation options arising from only three types of events: 1:5 year events, 1:40 year events, and 1:100 year over-wash events. However, the adaptation options could also generate benefits when other events occur;
- some benefits of adaptation—avoided injuries/ fatalities arising from severe events, damage to cars and crops or ongoing access to schooling—were not quantified. Significantly, the calculations are based on the assumption that only families located around the coastal road from Malem to Utwe relocate over time with improved access to the interior via a new inland road. In practice, relocation might not be restricted to these communities. Families from other parts of Kosrae might also benefit from improved access to the interior through relocating or using their own inland sites for agriculture production; and
- by opening up access to the interior of Kosrae, facilitating enhanced agricultural production while changing the dynamic of development away from the hazardous coastline and into the safer and more sustainable interior, the road could be expected to benefit communities beyond the 50 year period of this analysis, benefitting the community for generations to come.

As a result of these three issues, the potential benefits from developing an inland road now or in the future are quite certain to be higher than quantified.

Based only on those benefits quantified over a 50 year period and applying a four per cent discount rate, establishing an inland road now offers a modest payoff (NPV) of USD 0.37 million. When non-quantified benefits are taken into account, this payoff is expected to be substantially higher.

The option to establish the inland road now is preferable to establishing the inland road ten years in the future (NPV = USD –0.56 million) and 20 years in the future (NPV = USD –0.23 million), reflecting, in part, the increasing risks presented by sea-level rise and (potentially) cyclones.

- The option to establish the inland road now is also shown to be superior to the alternative course of action: to protect or upgrade the existing coastal road. These options were shown to generate a negative payoff (NPV = USD –2.16 million and USD –0.85 million, respectively). Moreover, there are a number of important limitations associated with these responses that are not fully captured in the aggregate results. Most importantly, the benefits of an upgraded coastal road specifically would only accrue to those families located *landward* of the road who would benefit from reduced inundation. By comparison, families located *seaward* of the upgraded road would remain in the direct line of the waves and continue to be affected by over-wash, with potential harm to family members or properties worsening over time as the sea level rises. As a result, these families would eventually still have to find an alternative means to adapt to the coastal threats. In community consultations, families in Malem and Utwe stated firmly that if the coastal threats are not addressed, the area will cease to be a safe and sustainable place for them to inhabit. They viewed that migration out of Kosrae or FSM is the only option remaining (Annex 2). Considering that Kosrae already represents the smallest state in FSM and that the island is presently experiencing a net loss of population due to outward migration (Division of Statistics undated), increased migration as a result of coastal threats may not be desirable both in terms of economic potential but also in terms of retaining Kosrean culture.
- Protecting or upgrading the coastal road can risk generating a false sense of security in the community, allowing families to believe that the area is now safe from inundation and *implicitly encouraging* further coastal development. Such an option is therefore counter to the State development plan intent of encouraging inland development as it can hamper relocation in the medium term. By comparison, establishing an inland road network facilitates relocation and opening up on the interior.
- There are likely to be additional environmental costs from establishing construction work such as protecting or upgrading of the road along the coast (such as downstream erosion). In the face of ongoing sea level rise, this construction would appear to be unwise.

Furthermore, the analysis shows that the inland road should only be pursued if funding can be secured for the full section of the road from Malem to Yeseng to Utwe. The calculated NPV of establishing a shortened road (from Malem to Yeseng) only is shown to be negative and is substantially lower than those values that could be achieved by establishing a complete road. This reflects the fact that a smaller proportion of the community will benefit while ongoing treatment of the existing coastal road remains. Equally importantly, establishing a portion of the inland road from Malem to Yeseng will leave the community of Utwe cut off from the rest of the community if the road becomes unpassable in future over-wash events. This is important for two reasons:

- First, ongoing threats will continue to undermine quality of life in the village, risking health and damaging possessions. In particular, damage to the road takes time to repair. While ‘minor’ over-wash events may cut off families for one or two days, extreme events (such as a near cyclone) could cause extensive damage which could take from days to weeks to repair. Ongoing interruption to family life, earnings, and education is important, especially in a community less advantaged than the rest of the Kosrae community.
- Second, as already indicated, the poor condition of the existing inland access roads brings into question the safety of the community in using these roads as escape routes. As a result, establishing a partial inland road does not address the quality of all the inland access and the immediate safety of the community. An advantage of establishing an entire inland road is rather that—should a sudden storm surge or over-wash event occur—families will all have immediate access to safe inland roads as an escape route while also having long-term access to the interior of the island for development or establishing new homes.

DISTRIBUTIONAL CONSIDERATIONS

Based on the quantitative analysis conducted, by far the greatest beneficiaries from the establishment on an inland road established today are families (compared to government), principally in the form of access to the interior of Kosrae to extend agricultural production. This is important because the communities of Utwe and Malem who stand to benefit first from the new road project already have the lowest average earnings in Kosrae, compared with communities in Lelu and Tafunsak. The opportunity to increase income and or food security through increased agricultural would directly improve the wellbeing of these families.

Moreover, these families already presently suffer a variety of harmful effects from over-wash, including reduced earnings (when access to work by hampered by road blocks), reduced educational opportunities (when access to school by hampered by road blocks) and reduced access to food (through the destruction of home gardens). The harmful impacts from these effects have a disproportional impact upon these communities as they already have the lowest average earnings in Kosrae, compared with communities in Lelu and Tafunsak. Ongoing over-wash can therefore suppress the economic vulnerability of the community. By comparison, a continually accessible road will minimise this harm and facilitate change, increasing the economic resilience of the community. While items values were not valued in the analysis in theory at least, an inland road project would contribute positively to both the food security and economic security of the community.

RELOCATION CONSIDERATIONS

Consultations held with stakeholders from Malem and Utwe revealed resounding support for an inland road and for relocation to the interior for safety and security. This support has also been affirmed in the present draft of the proposal for the road project (SPREP 2015b).

However, the rate at which families can move in practice will not be known with any certainty until the community can work through key issues in collaboration with government and policy makers:

- Relocation is likely to take time. The analysis presumes that relocation will be gradual. During this time, families who have not yet moved will continue to need access to the wider Kosrae community through a functioning road. Data analysis suggests that the cost of maintaining the existing coastal road for a few years will have a negligible impact upon the payoffs of a road. However, retaining a functional coastal road could act as a deterrent to relocation to safer ground and can implicitly discourage relocation. After 20 years, retention of the existing coastal road would require a new coastal road to be established, which is expensive. There would therefore be logic in establishing a new inland road network while (i) advising the community of the cessation of existing road maintenance at a specific point in time (e.g. 20 years or less) (ii) delivering a strategic campaign on relocation and agricultural development inland, and (ii) providing the community with reasonable lead time for their relocation while minimising costs.
- An average house in Kosrae has a replacement value of around USD 43,000 (Section 4.7). Few family members have access to such money to establish a new house once an inland road is established. However, with financial assistance, relocation could be rapid as the community are keen to relocate for safety's sake. As indicated in Section 5, faster relocation produces higher net benefits from relocation. There is therefore logic in the Kosrae State government reviewing access to housing loans or resources for relocation.
- Relocation from the hazardous coast is unlikely to happen while development continues unconstrained along the coast. In the face of sea level rise and climate change, it is unsustainable and unsafe for any new developments to be allowed to continue in hazardous areas such as the Malem to Utwe coastline. In the interest of public safety, no new developments should be permitted here. This constraint would then create a higher drive for developments in safer areas.

- Interim development in hazardous areas such as the Malem to Utwe coastline should be subject to appropriate building standards. In the face of sea level rise, ground level developments would appear to be unsound. Engineers in the State and or national government should be able to recommend clear standards which State government should actively enforce for the safety of the community.
- To support a new inland road and address the points raised above, a strategic communications campaign is required. This campaign should include messages such as why the old road will eventually not be maintained, why new developments along the coastline are not supported, how government can support families in relocation, and so on.
- Ultimately, and as indicated in SPREP (2015b), a relocation committee is needed to clarify relocation issues.

FOOD SECURITY CONSIDERATIONS

The largest component of quantified potential benefits from establishing an inland road from today is increased agricultural activity from opening up the interior of the island. At the same time, the impact most commonly reported from over-wash was loss of subsistence crops in existing home plots. The cost of lost crops was not quantified in this analysis. However, considering that home gardens provide a common source of food in Kosrae, and in view of the likelihood that a representative home includes at least three young dependents, the negative impact of coastal inundation on food security is likely to be increasingly significant over time.

Ongoing damage to food gardens harms food security for the affected communities, and this damage is likely to worsen with time. Efforts to open up the interior for safe agricultural development would assist in this. There is therefore likely to be value in accompanying the establishment of an inland road with a campaign to encourage the adoption of sustainable inland agriculture.

OTHER ISSUES

A number of issues concerning the road relocation are uncertain. First, the impacts of climate change adaptation projects are unclear. What is the potential environmental impact of major construction work along the coast or inland? While major projects bring potential risks, they might also bring opportunities. Would opening up the interior of Kosrae provide access to cultural sites hitherto denied to the community because they could not access the area? Would this bring harm? What are the potential environmental impacts of different adaptation options? These matters would presumably need to be considered in an EIA should the road project proceed. Any identified risks would need to be built into a monitoring plan for the project to optimise benefits for the State.

Similarly, the rate of relocation promised by the road project is still unclear. While community enthusiasm for the project is high, relocation depends on access to resources. It is therefore logical that the means and speed of relocation of the community should be monitored as part of the project, should it proceed.

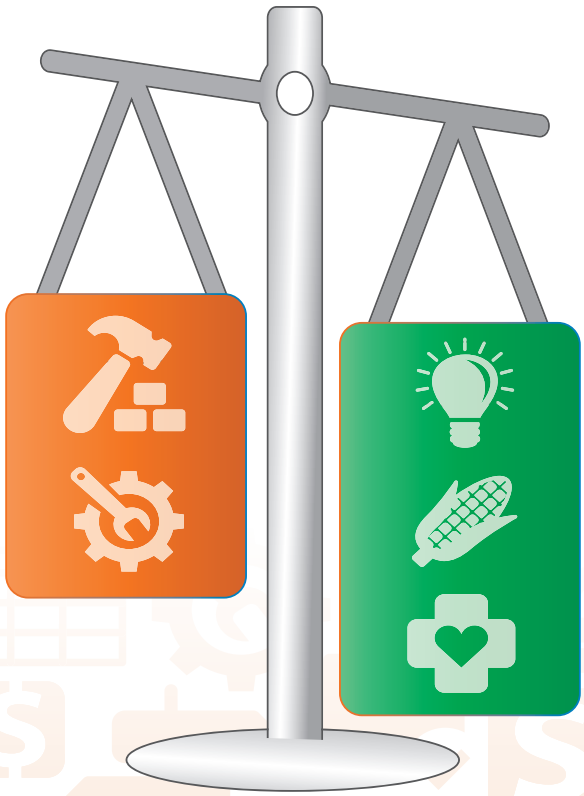
Government presently routinely collects little documentation of the actual effects of over-wash on the government, private sector, or community. This analysis relied heavily on a key 2008 assessment of the effects over-wash. Documentation of disaster events provides the foundation and business case for future remedial action. Government should consider documenting the impact of future events including noting impacts such as impacts of housing and estimated cost of repairs or other remedial action. These data should be stored for future reference.

Introduction

This report documents a cost benefit analysis (CBA) of coastal road relocation in Kosrae. The report builds on and extends preliminary economic analysis conducted with the Kosrae State Government in early 2015, conducted as part of a capacity building exercise (SPREP 2015a).

The objective in the CBA presented here is to identify economic issues around a project to relocate a coastal road in the face of climate change and sea level rise, identifying:

- the value for money of alternative coastal infrastructure options in the face of sea level rise and climate change;
- the degree to which any coastal infrastructure option might be pursued as a high-priority infrastructure investment; and
- the extent to which key risks and uncertainties might potentially affect the realisation of potential benefits and value for money.



1. Background – Malem Coastal Zone Management Project Proposal

1.1 Coastal development threats around Kosrae

According to the Kosrae Shoreline Management plan (KIRMA 2014), much community and infrastructure development in Kosrae over the last few decades has occurred within the coastal margins. However, much of the area in which this coastal development has occurred is susceptible to coastal hazards, such as long-term coastal change and episodic coastal inundation (especially during spring high tides) (KIRMA 2014, p. 11). For the foreseeable future, the effects of climate change, particularly sea level rise, are likely to exacerbate the threat of inundation to coastal developments and loss of infrastructure, such as sections of the road network.

Based on the Kosrae Shoreline Management Plan, the areas most vulnerable to coastal inundation include the coastal area between Malem and Utwe (Figure 1). The road connecting these two communities runs parallel to the coast, on a narrow storm berm (raised bank) and is precariously close to the sea, at risk of over-wash and increasingly at risk of being breached (Figure 2). The community, road, and infrastructure in the area have faced numerous inundation events, with coastal homes in Malem and Utwe exposed to regular (annual) over-wash, particularly during spring high tides when larger waves can reach the shoreline. Severe damage due to tropical cyclones is a rare occurrence on Kosrae, with the last notable event occurring in 1905. However, cyclones often form close to Kosrae or track close to the island as they develop, with increased risk during El Niño conditions, the last being Tropical Storm Dolphin in May 2015. While wind damage from these events is relatively minor, large swell waves can cause damage along the Utwe and Malem coasts.

Work conducted by KIRMA has identified that, in a potential inundation event, approximately 104 buildings are potentially exposed to over-wash/inundation on the stretch from Malem to Utwe. These buildings include 98 houses, one church, three businesses, one playground, and one school (Figure 1, page 1). Twenty-five homes are located seaward of the road, and 73 are located behind (landward of) the road.

The effects of wave over-wash and inundation events include flooding of homes, damage to vehicles, and blockages/breaching of the road. At present, approximately 120 metres of road at Mosral and 200 metres of road at Paal are critically exposed and at risk of being breached at any time. Such a breach cuts off the village of Utwe (population approximately 983) and removes road access to Walung (population approximately 268) as well as potentially disrupting utilities (power and telecommunications) which run parallel to the road (often precariously close to the shoreline; Figures 3 and 4).

Ongoing shoreline change is also expected to result in an ever-increasing length of road becoming critical exposed to wave damage within the next decade and beyond, including a further 450 metres section south of Mosral to Kuplu, 500 metres from Paal to Malem river mouth, and approximately 1 kilometre from Kuplu to Utwe (Doug Ramsay, Manager Pacific Rim, NIWA, personal communication, June 2015).

The infrastructure exposed to shoreline change and wave over-wash damage in Malem encompasses road, power, water, and telecommunication lines which run parallel to the road. The power lines at certain sections like Paal and Mosral are fully exposed to wave damage and corrosive salt spray (Figure 3). Inundation and over-wash from large waves and spring tides, particularly in the November to February period, are normal occurrences given the increasingly receding coastline and low elevation of the road in this area. Some households are inundated during such events, and exposure of vehicles, running over sea water inundation and over-wash happens yearly.

FIGURE 2. ROAD EXPOSED TO OVER-WASH

FIGURE 3. EXPOSED POWER LINES ALONG COASTAL ROAD

FIGURE 4. POWER UTILITIES PROPPED UP ON NEARBY SHORELINE

FIGURE 5. BARELY DISCERNIBLE ACCESS ROAD (FINSREM INLAND ACCESS ROAD)

1.2 Causes of the problem

The problem of coastal inundation is founded in a number of contributory causes. First, the southern coastline is naturally exposed to active wave action and ongoing erosion. The establishment of the coastal road in late 1940s and early 1950s and other development on Kosrae involved the removal of large amounts of coastal rubble from the beach and reef flat, resulting in the loss of natural protection along much of the eastern-facing coastline (KIRMA 2014, p 65–66).

Second, the road and much development are located on a narrow (10–50 m wide) storm built berm, with inter-tidal wetland or mangrove between the berm and the volcanic part of the island. This land area is highly dynamic and highly exposed to coastal change and coastal inundation. With sea-level rise, present-day very high tide levels that cause inundation problems at present will become ever more frequent (KIRMA 2014, p 93).

Third, the establishment of the road and associated infrastructure has focussed development along this exposed coastline. Unfortunately, over the period of significant development since the Second World War, limited information and understanding existed at the time of settlement about the scale of hazard risks in this area. Not only are houses now exposed to the coastal hazards, but infrastructure

critical to the livelihoods and well-being of coastal villagers is also now at increasing risk from inundation and coastal change.

Fourth, much of the land in Kosrae is privately owned. This means that some families occupying the coastline cannot automatically relocate inland where they do not themselves own the land. In truth, even if families had access to land inland, the fact that the public road infrastructure focuses on coastal access constrains householders from independently adapting to climate risks by moving inland away from the coast.

1.3 Climate change

According to the Government of Australia (2011; 2014), temperature rise has been recorded as increasing generally for FSM in recent years, while a clear decreasing trend in annual and wet season rainfall has been observed.

For the future, the Government of Australia (2011; 2014) predicts that:

- air temperature and sea-surface temperature will increase;
- the number of hot days and warm nights will increase;
- there will be an increase in average annual and seasonal rainfall;
- droughts will become less frequent; and
- extreme rainfall days are likely to occur more often.

Sea-levels are also rising around Kosrae and can be expected to continue to do so for the next few decades (e.g. Government of Australia 2014). In light of this, the probability of over-wash events and inundation of low-lying coastal land will likely increase with climate change, especially given sea level rise.

1.4 Objective of the project

The Pilot Programme for Climate Resilience: Pacific Regional Track (PPCR-PR) is a regional programme that aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes. The PPCR-PR was implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) and Asian Development Bank (ADB) and funded through funded through the Climate Investment Funds (CIF). In light of the coastal threats being faced along the Malem to Utwe coastal corridor, the State Government of Kosrae, in tandem with SPREP and the PPCR-PR, is developing a proposal to establish an interior road that links Malem to Utwe, by-passing the need for citizens to rely on the 4.5 kilometre coastal road for access while ensuring the safety of people in the coastal area.

A secondary but important objective in the road project is to protect the long-term wellbeing of the Kosrae community by facilitating the relocation of families by opening up the interior. While relocation inland is presently difficult due to limited access, the opening up of the interior through an inland road would enable families to plan to relocate community infrastructure and properties, as new buildings are constructed or as existing buildings are upgraded, enabling new settlements to develop in areas not exposed to coastal hazards and the ongoing effects of sea-level rise. The importance of developing the interior of Kosrae island is presently in the Kosrae Strategic Development Plan, which stipulates that it is a national priority to 'divert development and settlement along the coast to inland and higher grounds … diverting development and settlement inland: improving inner roads and encouraging the citizenry to settle inlands' (Division of Economic Planning 2013, p 29).

1.5 Options

In view of ongoing natural coastal erosion processes, existing sea level rise trends and the present precarious location of the road, the establishment of an inland road has been identified as an option for adaptation in Kosrae that is sustainable in both removing essential infrastructure from being impacted by coastal hazards in Malem and Utwe while ensuring access to the community of Utwe (Figure 6). The establishment of an inland road is also a recognised national priority. The need for a new road inland to replace the present coastal road has been stipulated as the priority of the Kosrae Shoreline Management Plan (KIRMA 2014, p 32) and reinforced in the Kosrae Joint State Action Plan for Disaster Risk Management and Climate Change (Government of Kosrae, in press).

FIGURE 6. PROPOSED INLAND ROAD. SOURCE. KIRMA (2014)

To consider the economic implications of the new road project, and reflecting the terms of reference for this economic assessment (CBA) of it, several climate change adaptation scenarios are compared against a series of alternative adaptation options including coastal protection with revetment and upgrading the coastal road. In reality, the form of that these options and an inland road could take can vary. For example, revetment could cover the entire coastline or just parts; new coastal roads could be built to existing design standards or to new design standards. This analysis assesses selected forms of the adaptation options to consider a way forward for Kosrae:

- The value of *business as usual* – ongoing retention of the coastal road in the face of climate change and natural hazards. This scenario would result in ongoing (and potentially increasing) costs from coastal over-wash and breaching of the road. These impacts are described more in Section 2; and
- The value of mitigating coastal threats through the establishment of a new inland road or coastal defences. These scenarios would potentially reduce risks to the community (see Section 2). Considerable interest surrounds the inland road option which has already been the focus of preliminary costings (KIRMA 2014, p 32). In detail, the options compared are as follows:

1. Establishing a protective rampart (rock armoured revetment) to protect the coastline between Malem and Utwe. Revetment is a common form of coastal protection in the Pacific generally as well as specifically on Kosrae. (This adaptation option would accompany replacing the existing coastal road to its existing specifications; see Section 2.1 – *Revetment of the coastal road*);
2. Construction of inland road starting now and ending in 2017[1] (thus allowing two years for construction from the present day) and abandoning the existing coastal road;
3. Construction of inland road starting now and ending in 20171 (thus allowing two years for construction from the present day) and maintaining the existing coastal road for a period of ten years (after completion, to 2027);
4. Construction of inland road starting now and ending in 20171 (thus allowing two years for construction from the present day) and maintaining the existing coastal road for a period of 20 years (after completion, to 2037);
5. Construction of inland road starting now and ending in 20171 (thus allowing two years for construction from the present day) and maintaining the existing coastal road for a period of 50 years;
6. Construction of the inland road beginning in ten years (commencing construction 2026; completed 2028);
7. Construction of an inland road beginning in 20 years (commencing construction 2036; completed 2038);
8. Additionally, a new option is being included in this analysis, that of upgrading the existing coastal road to accommodate sea level rise and storm surge. This would involve elevation and strengthening of the road based as well as the use of Asphalt. An upgrade of this form was recently delivered by the Kosrae State Government in 2015 at the airport, although this did not include the asphalt layer.

Details are summarised in Annex 1.

1 SPREP terms of reference requested assessment of an inland road established from 2016. However, as it takes two years to construct the road, assessment of a functioning road would actually not be possible until from 2017.

2. Methodology

CBA is a systematic process for identifying, valuing, and comparing costs and benefits of a project. Multiple references exist on the methodology and principles of CBA (see for example, European Commission 1997; HM Treasury 2003; Tietenberg 2006; OECD 2006; Australian Government Department of Finance 2006; UNECE 2007; USEPA 2010). However, broadly speaking, the key features of a CBA are:

- all related costs (losses) and benefits (gains) of a project are considered, including potential impacts on human lives and the environment;
- costs and benefits are assessed from a whole-of-society perspective[2], rather than from one particular individual or interest group (that is, a public and not a private perspective is taken);
- costs and benefits are expressed as far as possible in monetary terms[3] as the basis for comparison; and
- costs and benefits that are realised in different time periods in the future are aggregated to a single time dimension (discounting) (Buncle et al. 2013).

The first issue of considering all costs and benefits from a project is fundamental to effectively interpreting any CBA. In theory, all the potential benefits and costs of a project are supposed to be assigned dollar figures when doing a CBA. However, it is common for cost benefit analyses to be completed in practice without all the benefits or costs of a project being values due to lack of data. In such cases, it is frequently impractical to assign values to certain benefits or costs because:

- the physical or monetary values simply cannot be reliably measured or established;
- the cost or benefit items are not significant to the analysis; and
- it is judged that the cost of attempting to value the cost or benefit outweighs the benefit of including them in the analysis (Buncle et al. 2013).

Where values cannot be quantified in practice for this analysis, they will be listed and analysed qualitatively. Their impact in relation to the value of climate change adaptation will be considered in more detail in the Implications Section.

2.1 Costs and benefits

WITHOUT CHANGE

Considering the precarious state of the road in places already, it seems unrealistic to assume that the State Government of Kosrae could continue to merely maintain the existing coastal road into the long term without investing in some major form of remedial work. It is more realistic to recognise that the government would ultimately need to at least replace the road in its current form. If this was done, ongoing impacts from over-wash would be expected to continue over time, but at least the road would not be crumbling into the sea as it is presently in some places.

Kosrae State Government advised that replacing the road in its present form would require substantial investment by the government, involving upgrading the road sub-base wearing course to a hot mix asphalt pavement (Leandro Olando, Civil Engineer, Department of Transport and Infrastructure, personal communication, October 2015). Additionally, NIWA (Doug Ramsay, personal communication, January 2016) advises that revetment along the most exposed parts of the coast (between Paal and Mosral, plus an additional stretch around the corner towards Utwe (Figure 7) is unavoidable to prevent ongoing damage. This is a length of coastline in the order of 2.5 km or 1.6 miles.

2 For this reason, some people refer to CBA as *social* CBA.

3 Note that costs and benefits that cannot be quantified in monetary terms are still considered during decision making.

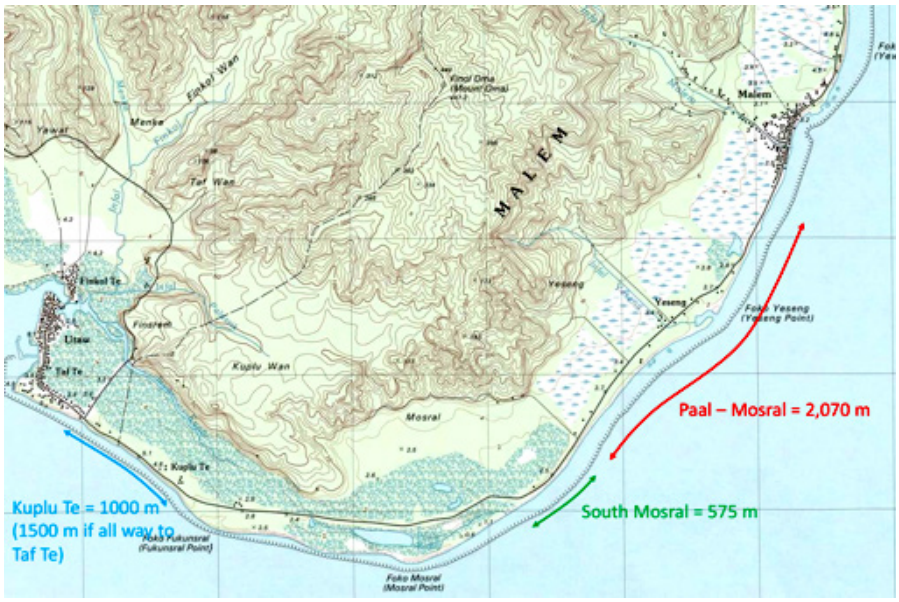


FIGURE 7. REVETMENT TARGETS

Source: Doug Ramsay

Ongoing sea level rise and climate-related hazards would continue to threaten the condition and operation of the present coastal road, resulting in an increased frequency and magnitude of over-wash and leading to road breaches and possible harm to both the community and their possessions (Table 1).

At present, the negative impacts from coastal over-wash include inundation and the risk of loss of sections of the road (Table 1). Over-wash leads to damage to property, households, crops, and vehicles. The frequency and severity of over-wash and resulting damage will increase with sea level rise. Maintenance of the existing road will likely become more costly.

Additionally, exposed sections of the road at Paal and Mosral are presently susceptible to being breached during an over-washing event. The likelihood of this happening and the length of road section over which it could occur will continue to increase. Residents in Utwe and affected areas around Malem then lack access to commercial, health, and education facilities, as well as the seaports and airports because these facilities are predominantly located in the northern part of the island. Furthermore, power and telecommunication lines built parallel to the existing road will also be affected, threatening services to the residents in Utwe and Malem. Ultimately, this infrastructure could be permanently unusable with road failure. Finally, access by people to the hinterland for farming is presently limited without a decent road. The existing inland roads are predominantly farm tracks of poor quality (Figure 5).

TABLE 1. BROAD POTENTIAL BENEFITS AND COSTS WITH AND WITHOUT THE NEW ROAD PROJECT

WITHOUT SCENARIO/ EXISTING ROAD REPLACEMENT	GENERAL WITH SCENARIOS		
	Revetment with coastal road replaced to existing specifications	Coastal road upgrade (elevated)	Inland road
Debris blocking the road and cost to remove	Reduction in over-washing and associated debris for lower return period events	No or reduction in over-washing and debris for lower-moderate return period events	No coastal-related debris to remove
Inundation of coastal houses	Limited expected change	Reduced risk of over-washing for landward homes No reduction in high-tide flooding which will increase in frequency with sea level rise	Reduced risk of over-washing for landward side homes No reduction in high-tide flooding which will increase in frequency with sea level rise
Damage to cars, garden crops	Some minor reduction in car damage. Reduced risk of over-washing affecting garden crops under lower return period events	Some minor reduction in car damage. Reduced risk of over-washing affecting garden crops under lower return period events	No car damage, no crop damage
Inability to get to work (Utwe and Malem) resulting in lost income	Continued access under lower/ moderate return period events. Loss of access under more extreme events	Continued access under lower/ moderate return period events. Loss of access under more extreme events	Continued access, no lost earnings
Inability to reach schools and hospitals	Continued access under lower/ moderate return period events. Loss of access under more extreme events	Continued access under lower/ moderate return period events. Loss of access under more extreme events	Continued access
Interruption of power, telecommunications – inconvenience for households, loss of earnings to utilities	No expected change under lower return period events. Interruptions and loss likely under moderate-high return period events	No expected change under lower return period events. Interruptions and loss likely under moderate-high return period events	No interruption for families No lost earnings for utilities
Damage to road and need for repairs	Reduced damage under lower return period events. Damage to roads will still occur under moderate-high return period events	Reduced damage under lower return period events. Damage to roads will still occur under moderate-high return period events	No repairs needed
Trauma and inconvenience	Reduced trauma/inconvenience under lower return period events. No expected change under higher return periods	Reduced trauma/inconvenience under lower return period events. No expected change under higher return periods	No trauma or inconvenience
Limited access to interior	No expected change	No expected change	Land access for increased farming
Road maintenance	Limited expected change	Costs to upgrade road	Costs to establish road
			Land Acquisition
	Require ever-increasing maintenance to provide serviceable road as sea level rise increases	Require ever increasing maintenance to provide serviceable road as sea level rise increases	Maintenance
	Possibility for increased erosion at the southern end of the wall	Possibility for increased erosion at the southern end of the wall	Environmental impacts?
			Awareness cost
			Cultural site impacts?
Land loss due to natural processes	Land retained	No expected change	No expected change

Sources: Blair Charley, KIRMA; Lipar George, ODA; Nena M. William, Office of the Governor, Kosrae State; and Doug Ramsay, NIWA, personal communication, October 2015.

Much property and community development landward of the road is located on low-lying land or has been reclaimed from inter-tidal mangrove or wetland areas and is barely above present-day high tide levels. High-tide inundation will become an ever-more frequent and significant occurrence as sea levels increase, irrespective of continued protection of the current road.

UPGRADE OF THE COASTAL ROAD

An alternative to replacing the road in its current form would be to replace the road but seek to protect it from sea level rise by elevating the road (approximately 6 inches to 1 foot; 15 to 30 cm) (Leandro Olando, personal communication, October 2015). Establishing an upgraded costal road would be expected to reduce the damaging effect of minor inundation events on the road (reducing road repair and clearance costs) and reducing the frequency at which the coastal road is blocked. The effect on housing would vary, with homes seaward of the road receiving no benefit, but those behind it potentially benefitting from some reduction in over-wash.

Establishing an upgraded coastal road could potentially encourage further development of the coastal strip between Malem and Utwe because of the perception that coastal over-wash and inundation would no longer be a threat so families could safely invest further. In such a case, household numbers along the coastal fringe could be expected to increase. Discussions between State Government of Kosrae representatives and SPREP (Buncle 2015) confirm that government believe this would happen if any major construction, such as an upgraded coastal road and revetment, is established.

Establishing an upgraded coastal road would involve costs, including upgrading the sub-wearing course to hot mix asphalt pavement as well as elevating the road. Theoretically, such an elevated road would limit the scope for over-wash and damage from severe events. Additionally, NIWA advise that revetting of the critical 1.6 miles of highly vulnerable coast between Paal and Mosral and around the corner towards Utwe would still be required.

Additionally, NIWA states that any major construction work along the Malem coastline would likely result in down-drift erosion impacts. The extension of the existing rock wall along the southern part of Malem village has been a significant factor in the accelerated erosion problems at Paal. Likewise, the engineering structures at the outlet of the Mosral stream have increased the erosion immediately to the south (Doug Ramsay, personal communication, January 2016). Consequently, there are likely to be some environmental costs from coastal road works.

REVETMENT OF THE COASTAL ROAD

A cheaper alternative might be to revet the coastal area to limit the potential for breaching of the road and provide increased protection from over-washing. This would provide short- to medium-term protection of coastline and road.

The level of protection provided from over-washing will depend on the design of the revetment, but it would be expected that overtopping could be significantly reduced for low- to moderate-severity events. However, revetment alone would be unlikely to reduce overtopping volumes sufficiently to prevent damage from large swell caused by cyclones forming or tracking close to Kosrae or due to cyclone passing directly over Kosrae (Doug Ramsay, personal communication, January 2016).

Moreover, the level of protection would ultimately decrease as sea levels rise, and, given the low-lying nature of the land levels behind the revetment, this option would not stop the increased frequency and severity of high-tide inundation that will occur with sea-level rise. As a result, NIWA recommend that revetting the coastline should only be considered as an adaptation option that *accompanies* other solutions, not considered on its own as its effectiveness relies on accompanying

measures. To this end, revetment of the entire coastline is only considered in this analysis as an accompaniment to the replacement of the coastal road in its present state.

As suggested for the upgraded coastal road option, establishing revetment could potentially encourage further development of the coastal strip between Malem and Utwe because of the perception that coastal over-wash and inundation are no longer threats. In such a case, revetment works could reduce the likelihood of households relocating voluntarily (potentially increasing them over time, in fact) and increase the difficulty and timeframes available for relocation to occur in the future. Discussions between State Government of Kosrae representatives and SPREP (Buncle 2015) confirm that government believe this would happen if any major defensive coastal infrastructure, such as an upgraded coastal road and revetment, is established.

Establishing revetment would involve construction costs and might have some impact upon the coastal environment. Additionally, and as indicated for coastal road upgrades, NIWA linear construction along the Malem coastline would risk down-drift erosion impacts (Doug Ramsay, personal communication, January 2016). Consequently, there are likely to be some additional environmental costs from coastal road works.

INLAND ROAD NETWORK

Compared to protecting the existing road, re-establishing the road inland would remove essential infrastructure from being impacted by coastal hazards or the impacts of sea-level rise for this century and beyond (Table 1). It would ensure permanent access to Utwe and the Malem community south of Malem village.

In the medium term, opening the interior through a new road network could facilitate community and relocation away from the hazardous coast. It is impractical for families to relocate presently because no access road or other essential infrastructure exists for the hinterland, and families need to be located near to public infrastructure. With a new road, power and telecommunications lines would be expected to be permanently relocated with the new road, thereby ensuring continued long-term utility access to residents in the affected areas. It would also mean that inundation of homes and crops would cease as people would move away from the coast.

Establishing an inland road would involve construction costs and require the purchase of the land. KIRMA (2014) propose that an inland road project be accompanied by an awareness campaign to maintain support from stakeholders to share land for road construction as well as to allow the opening up of the interior for relocation.

If an inland road network were established today, a replacement coastal road would not need to be established. However, given the state of the existing coastal road, delays in the establishment of a coastal road network or long-term use of the existing road while migration occur would mean a replacement coastal road would be needed because the road is presently is poor condition in places.

Potentially, environment and cultural impacts could arise from the construction of a road inland. According to the Kosrae State Government (Andrew Standon, Heritage Protection Office, personal communication, October 2015), the interior of Kosrae has not been surveyed for cultural amenities although it is known that many of the pre-missionary villages were located around the base of the volcanic part of the island (Rainbird 2004; Swift et al. 1997). It is presently unclear if the proposed route for the inland road would threaten any culturally valuable sites. For the same reason, it is also unclear the extent to which access to the interior by a new road would increase access by the local community and/or tourists to cultural sites for social benefit. These matters would presumably need to be considered in an environmental impact assessment should the road project proceed.

3. Data

3.1 Baseline data

COSTS ASSOCIATED WITH THE EXISTING ROAD

According to DT&I, the engineering standard of the present coastal road should allow for a life span of approximately 30–40 years, provided it is adequately maintained (Leandro Olando, personal communication, October 2015). However, the road is already long established, and parts of the road around Paal and Mosral and around the corner toward Utwe are already perilously close to the sea and crumbling. Consequently, the existing coastal road would ultimately need to be replaced. DT&I consider that the existing road would barely last another five years if these areas are not revetted. However, with revetment of the more vulnerable parts of the road and sufficient maintenance, the existing coastal road could perhaps last up to another 20 years (Leandro Olando, personal communication, October 2015). After this time, the entire road would need to be replaced anyway.

In practice, it is unclear when the revetment of the areas around Paal and Mosral would be conducted and when the road would be replaced to its present technical specifications. Upon agreement with stakeholders (Buncle 2015), it is assumed for illustrative purposes that, because of the perilous state of the road around Paal and Mosral and towards Utwe, the revetment occurs immediately and the road is replaced now over a two year period, subsequently being replaced again in 35 years (the average of 30 and 40 years).

Replacing the road in its current form would involve upgrading the road sub-base wearing course to hot mix asphalt pavement at a standard cost of approximately USD 520,000 per mile (1.6 km) (Leandro Olando, personal communication, October 2015). It is assumed that upgrading the coastal road between Malem and Utwe would take two years.

The coastal road would need to be maintained over time. The existing road is presently maintained using a share of Government's annual provision for road up keep. However, no record is kept of the amount spent to maintain that portion of the state's road network. KIRMA (2014) indicate that upkeep of an inland road would be in the vicinity of two to five per cent of the total road construction costs, over the life of the road (50 years). A similar approach was taken by Rios Wilks (2013). Using this approach, the upkeep of the road between Malem and Utwe is estimated as two per cent of the construction cost of a replacement road, spread over the life of the road (50 years).

3.2 Coastal protection construction

REVETMENT

Data on construction costs were sourced from the Kosrae State Government (Leandro Olando, personal communication, October 2015). According to DT&I, the normal expected lifespan of revetment along the coast of Kosrae is in the order of 50 years. Costs to establish it are summarised in Table 2. Costs for revetment are based on a standard cost formula of USD 600,000 per mile (1.6 km) used by the state government. Revetment of the coastline from Malem to Utwe is assumed to take two years whereas revetment of the small portion of land around Paal and Mosral is expected to occur within a year. Maintenance for revetment is assumed at two per cent per cent of total construction costs, spread over 50 years. This is consistent with the principle by KIRMA (2014) of assigning two per cent maintenance costs towards effective maintenance of a new inland road.

Where revetment is delivered in support of other options, revetment of the entire coast would not be necessary: only of specific parts of the road most at risk. As indicated in Section 2.1, these are the coastal area between Paal and Mosral, plus an additional stretch around the corner toward Utwe (Figure 7). This generates a length of coastline to be revetted in the order of 2.5 km or 1.6 miles.

COASTAL ROAD UPGRADE

According to DT&I, the normal expected lifespan of an upgraded coastal road is on the order of 50 years (Leandro Olando, personal communication, October 2015). Estimated costs to upgrade the coastal road are based on state government estimates to upgrade the sub-wearing course and upgrade the sub-wearing course to hot mix asphalt pavement (see Table 2). This represents a cost of approximately USD 820,000 per mile to USD 300,000 per mile to elevate (approximately 6 inches to 1 foot, or 15 to 30 cm) the road, plus USD 520,000 per mile to upgrade the sub-wearing course to hot mix asphalt pavement (Leandro Olando, personal communication, October 2015). Additionally, based on discussions with NIWA (Doug Ramsay, personal communication, January 2016), establishment of an upgraded road would require revetment around the 1.6 miles of critically exposed areas of the coastal road around Paal and Mosral and the stretch around the corner toward Utwe.

As with revetment:

- It is assumed that upgrading the coastal road between Malem and Utwe would occur over two years.
- Maintenance for upgrading the road is assumed at two per cent of total construction costs, spread over 50 years, which is consistent with the principle by KIRMA (2014) of assigning two per cent maintenance costs to effective maintenance of a new inland road.

TABLE 2. ALTERNATIVE COASTAL PROTECTION COSTS

FORM OF PROTECTION	USD
Costs to revet coastal road Utwe to Malem	960 000
Costs to upgrade coastal road Utwe to Malem	5 338 200

Source: Leandro Olando, Civil Engineer, Department of Transport and Infrastructure, personal communication, October 2015.

3.3 Inland road

ESTABLISHMENT COSTS

According to DT&I, and based on the engineering data provided in KIRMA (2014), a new inland road network should have a life span of approximately 50 years, provided it is properly maintained. Depending on the speed at which communities relocate from the hazardous coastal area, DT&I consider that an inland road would need to be accompanied by revetment of the most vulnerable coastal areas (e.g. the area between Paal and Mosral; see Section 3.1). This is because neglect of this portion of the road will ultimately result is road failure. This move would 'buy time' for the community to relocate (Leandro Olando, personal communication, November 2015). Based on consultations held with multiple stakeholders in 2015 (Buncle 2015), the State Governance of Kosrae believe that the existing coastal road would need to be maintained generally and revetted specifically at specific locations if relocation of the community away from the hazardous coastal area is not sufficiently fast.

The Kosrae State Government initially estimated the costs to establish an inland road network in 2014 (KIRMA 2014), but updated these costs in 2015 (Leandro Olando, personal communication, October 2015). Revised cost estimates include road and utility construction, water, power, and telecommunications facilities (Table 3). Lifetime maintenance costs for the new road are assumed at two per cent of total construction costs, spread over the life of the road (KIRMA 2014).

TABLE 3. ESTIMATED INLAND ROAD NETWORK CONSTRUCTION COSTS (INCLUDES WATER, POWER, AND TELECOMMUNICATIONS)

	TOTAL USD
Malem to Yeseng	1,467,039.54
Access Road Malem	475,986.29
Access Road Yeseng	273,555.35
Inland Yeseng to Finsrem	3,183,177.56
Access road Utwe to Finsrem	328,266.40
Total construction cost	5,728,025.14

According to DT&I, it would take approximately two years to construct the inland road and utilities. As a result, construction costs were annualised over these years.

The costs to revet the area between Mosral and Paal were taken from DT&I. Additionally, values were estimated for land purchase (see Land Values) and an awareness-raising campaign. According to DT&I, an awareness campaign costs an average of USD 5,000 given that the target group is all four villages of Kosrae. It would usually be delivered in two rounds: one before implementation and one after implementation. As a result, costs were divided into two blocks of USD 2,500: one prior to construction (year 0) and the second at the completion of the road (year 2). Total estimated costs are summarised in Table 4.

No estimates were made of environmental or cultural impacts associated with any of the construction options.

TABLE 4. ROAD AND UTILITY ESTABLISHMENT COSTS (2015 PRICES)

ITEM	USD
Road construction	5,728,025
Land purchase	342,571
Awareness campaign	5,000
Environmental impacts	Not costed
Maintenance costs	2% construction costs over time

3.4 Population growth

Population along the coastal fringe between Malem and Utwe is assumed to remain stable, except when extensive defensive coastal developments, such as upgrading the coastal road or revetment, occur. In this case, it is assumed that household numbers for the coastal fringe between Malem and Utwe increase gradually over time as families perceive that the threat of over-wash or inundation no longer exists. Such a population increase implies that while the damage or losses (e.g. lost earnings) to households from over-wash would be expected to fall with enhanced coastal roads or revetment, these lower costs would nevertheless grow slightly over time as the number of households in the hazard areas swells.

Government representatives (Buncle 2015) recommend using an annual population rate of increase along the coastline of three per cent per annum. This is also the target indicator for GDP growth (Division of Economic Planning 2013). In practice, it is unlikely that the population of families along the coastline would continue without end. There is limited space for families to settle. For the purpose of illustration, it is assumed that additional growth along the coastline would remain stable once total household numbers swell to from the present level by 150 per cent (from the present 98 households to 147 by 2031).

3.5 Land values

The price to secure land for a new road was based on a 2006 assessment of land valuation conducted by ADB (ADB 2006). Costs were indexed to 2015 using CPI data from the Department of Statistics and presuming an average ongoing CPI of four per cent per year.

3.6 Cost of damage from coastal over-wash

FREQUENCY OF OVER-WASH EVENTS

Estimates of the likely costs of inundation that would be faced without adaptation to climate change were founded on estimates of the regularity (return frequency) of over-wash events. Return frequencies were estimated on the basis of observed inundation events reported in KIRMA (2014), as well as expert opinion from:

- the Kosrae State Government (Blair Charley, KIRMA; Lipar George, ODA; Nena M. William, Office of the Governor, Kosrae State); and
- NIWA (Doug Ramsay, personal communication).

The events used to underpin estimates of impacts costs are noted in Table 5, with the assumptions used noted in the final column.

TABLE 5. EXPERT OPINION-BASED ASSUMED RETURN FREQUENCIES FOR INUNDATION EVENTS

EVENT	IMPACT	RETURN PERIOD	RETURN PERIOD ASSUMED	VALUES QUANTIFIED?
General over-wash	• Minor – road temporarily blocked with sea water – vehicles able to wade through, but can sustain damage, minor debris	Several times per year when larger than normal waves coincide with high tides	Nov to April (high tide season) with vulnerable areas like Paal and Mosral affected daily	No
Extreme high tides (high king tides) e.g. 2008 event	• minor-moderate damage to the road damaging part of the carriageway e.g. at Mosral and at Paal • vehicle passage still possible in some areas but road breaches around Mosral given receding shoreline in that area • Some over-washing damage, flooding: • two homes destroyed, four with major damage, five with minor damage, seven affected*	5-7 yearly	5 yearly	Yes, based on Government of Kosrae (2008)*

Cyclone tracing close to Kosrae causing large swell waves	• breaching of the road around Mosral and Paal – vehicle passage not possible
	• minor-moderate road damage, over-wash damage to road
	• moderate damage to property located landward of the road between Malem and Utwe (toppings/roofing damage but walls potentially still standing; associated flooding impacting homes) and some minor damage to properties located behind the road:
	  • 25 homes are located seaward of the road** sustaining major damage
	  • 73 located behind the road** sustaining minor impact.
		1:30-40 yearly	40 yearly	Yes

Cyclone with a direct hit on Kosrae	• Has not happened since 1905
	• Multiple breaching of the road around Mosral, Paal, Malem
	• Vehicle passage not possible
	• Extensive damage expected for home seaward of the road (toppings/roofing ripped off but walls potentially still standing. Associated flooding impacts.) Lesser damage for homes landward of the road:
	  • 25 homes are located seaward of the road** completely destroyed
	  • 73 located behind the road** sustaining major impact.
		75-100 yearly	100 yearly	Yes

*Sources: Blair Charley, KIRMA; Lipar George, ODA; Nena M. William, Office of the Governor, Kosrae State; and Doug Ramsay, NIWA, personal communication, October 2015; * Government of Kosrae (2008); ** KIRMA database.*

In practice, more over-wash events than these three types would occur over the life of a road and in the future. Smaller annual events, biannual events, and other events would also be mitigated by adaptation options. These three events will be used as the basis of the minimum costs of over-wash, but logically, any quantified payoffs for adaptation options are likely to be substantially underestimated.

CLIMATE CHANGE EFFECTS ON THE FREQUENCY OF OVER-WASH EVENTS

Reviews of climate change assessments (Government of Australia 2011, 2014) indicate that there is very high confidence that mean sea-level rise around FSM will continue as a result of climate change. More recently, KIRMA (2014, p 93) estimate that, by the:

- 2030s, the high tide level of two metres will be exceeded by 12 per cent of all high tides;
- 2050s, the high tide level of two metres will be exceeded by 27 per cent of all high tides; and
- 2070s, the high tide level of two metres will be exceeded by 69 per cent of all high tides.

It is assumed that a 1:5 year event is represented by such an extreme high tide. As a result, these increases in frequency are used to illustrate future increases of 1:5 year over-wash events (Table 6).

TABLE 6. FUTURE % INCREASES IN 1:5 YEAR-TYPE OVER-WASH EVENTS

	2030	2040	2050	2060	2070
% increase	12	19.5	27	48	69
Data source	KIRMA (2014)	Average of increases between 2030 and 2050	KIRMA (2014)	Average of increases between 2050 and 2070	KIRMA (2014)

Compared with an expected increase in high tides, Government of Australia (2014) states that tropical cyclone numbers can be expected to decline in the future. However, such a projection is only made with low to moderate confidence as individual assessments vary in the extent to which they project cyclones staying the same or decreasing. Based on the qualitative assessment provided in 2014 and consultations with staff familiar with the field (Gillian Cambers, Project Manager, Global Climate Change Alliance: Pacific Small Island States Project, SPC, personal communication, October 2015) a conservative rate of change in the frequency of tropical cyclones is provided for illustrative purposes:

- No change in the frequency of tropical cyclones is assumed before 2050; and
- A five per cent reduction in the incidence of tropical cyclones is assumed to occur between 2050 and 2100. This is assumed to be a steady reduction over the 50 year period to 2100 (Tables 7 and 8).

The change in impacts resulting from ongoing climate change is assigned each decade for indicative purposes.

TABLE 7. FUTURE % DECREASES IN 1:40 YEAR-TYPE OVER-WASH EVENTS

2030	2040	2050	2060	2070
0	0	0	-1	-3

Source: SPC interpretations of Government of Australia (2014)

TABLE 8. FUTURE % DECREASES IN 1:100 YEAR-TYPE OVER-WASH EVENTS

2030	2040	2050	2060	2070
0	0	0	-1	-3

Source: SPC interpretations of Government of Australia (2014)

IMPACT OF OVER-WASH EVENTS ON CLEAN UP COSTS

Kosrae State Government estimate clean-up costs for a large swell event (1:25 to 1:30 year recurrence) event in the vicinity of USD 10,000 (Norinston Joe ODA, personal communication with Abraham M. Bahillo, Department of Transport and Infrastructure, March 2015). These costs would likely underestimate the cost of cleaning up debris after a 1:40 year event but are used as a conservative estimate.

Estimates for the cost of cleaning up after a 1:100 year event were not available but are logically to be higher than those of a 1:25 to 30 year event. An illustrative clean-up cost of USD 20,000 is imputed for cleaning up after a 1:100 year event.

Estimates for a 1:5 year event were not available. An illustrative cost of USD 2,000 has been imputed for clean-up costs following a 1:5 year event in the absence of any other data.

VALUE OF HOMES AT RISK

According to the Pacific Risk Information System (PacRIS; see http://pcrafi.sopac.org/about/), approximately 348 dwellings are assigned to Utwe municipality with an estimated total replacement value of USD 11,815,521 in 2009 terms (Litea Biukoto, Hazard Specialist, SPC, personal communication, March 2015). This means the average cost of a dwelling is approximately US 33,953, or USD 43,119 each in 2015 values.

IMPACT OF OVER-WASH EVENTS ON HOUSING

State of Kosrae (2008) indicates the scale of impact from an extreme high tide event that hit Kosrae in 2008. As indicated in Table 5, the 2008 event was estimated to be expected to recur on average every five to seven years (Doug Ramsay, personal communication). The damage information documented in the 2008 report was used as the basis of estimates of the expected costs of future five yearly (1:5 year) over-wash events, if no adaptation occurred. State of Kosrae (2008) documents considerable damage from over-wash to housing around the southern coast between Malem and Utwe (Table 5), resulting in two houses totally destroyed, four houses sustaining major impact, five sustaining minor impact, and seven houses affected.

In practice, the meaning of houses sustaining ‘major damage’, ‘minor damage’, or ‘affected’ by the 2008 event was unclear, making it difficult to estimate the actual cost of housing damage. As a result, discussions were held with representatives of the Kosrae State Government (KIRMA, ODA, Office of the Governor) to generate ‘representative’ estimates of the extent of damage implied by major damage, minor damage or affected. The resulting indicative rates of damage for the terms are presented in Table 9, with assumptions noted in the final column.

TABLE 9. LEVELS OF HARM TO HOUSING (2008)

IMPACT TERM	TYPE OF DAMAGE	ILLUSTRATIVE EXTENT OF HOUSING DAMAGE %	ASSUMPTION USED %
Destroyed	Amount of damage requires new construction or complete renovation	80–100%	90
Major Damage	Unsafe to live in until repairs are made	40–80%	60
Minor damage	Inhabitable but need repairs, cleaning and clearing	20–40%	30
Affected	Need cleaning and clearing	5–20%	12.5

Source: Blair Charley, KIRMA; Lipar George, ODA; Nena M. William, Office of the Governor, Kosrae State, personal communication, October 2015.

For less common, more extreme events (1:40 year event, 1:100 year event), no documentation exists on the observed impact on housing. As a result, discussions were held with officials of the Kosrae State Government to consider the likely effects of over-wash from storms. Staff drew on accounts of previous events including the 1905 typhoon that hit Kosrae. Drawing on data from KIRMA of the number of houses seaward of the road and landward of the road, illustrative estimates of possible damage were generated (Table 6).

IMPACTS OF OVER-WASH EVENTS ON ROAD REPAIR COSTS

Over-wash over time can result in damage to the coastal road. Based on discussions (Doug Ramsay, personal communication, October 2015):

- a 1:5 year event could result in minor to moderate damage of the road requiring reinstatement of the shoulder or damage to part of the carriageway;
- a 1:40 year event could result in moderate damage along seaward edge of road along exposed sections (1.6 miles, or ~2.6 km; see Section 3.2), affecting the shoulder as well as undermining the carriageway (loss of parts of the tar surface); and
- a 1:100 year event could cause significant damage along the 1.6 miles seaward edge of road along exposed sections.

State Government of Kosrae advised that over-wash events leading to potholes, etc., along the main paved road of Kosrae would incur road repair costs in the order of USD 5,500 per mile (Leandro Olando, personal communication, October 2015). These figures were used to calculate road repair costs for a 1:5 year event. By comparison, damage from a 1:40 and 1:100 year event would likely require major structural repairs including replacement of the sub-wearing course (Doug Ramsay, personal communication, January 2016). The costs for replacement of these items were based on the full costs of road repaid power mile affected (USD 520,000 per mile; see Section 3.1) and expert opinions of the extent (length) of road damage (Doug Ramsay, personal communication, January 2016) (Table 10).

IMPACT OF OVER-WASH EVENTS ON THE COMMUNITY

Recorded data on the impact of inundation events on families does not appear to exist. In its absence, consultations were conducted with the communities most impacted by inundation on the affected coastline: Malem and Utwe (Annex 2). Community representatives were invited to complete a questionnaire on the effect of coastal inundation and over-wash as well as to share views on how the issue should be tackled. Based on the data provided, it would appear that a representative household in Malem or Utwe:

- contains seven family members, of whom at least three are under the age of 18;
- has been affected by inundation of the coastline, with their home garden being harmed or totally destroyed, affecting their access to food; and
- has experienced negative impacts on utilities from over-wash—most likely power outages—but otherwise affecting their access to shops, work, or other facilities.

According to the consultations, 63 per cent of respondents had experienced the effects of over-wash, with the 2014 over-wash event being the most commonly recalled event (affecting a third of affected respondents). The 2014 event was a high (King) tide, similar to the 2008 over-wash event which has with an expected return frequency of approximately 1:5 years.

TABLE 10. ROAD DAMAGE AND OTHER COSTS WITHOUT ADAPTATION

MINOR EVENTS	5 YEARLY EVENTS	40 YEARLY EVENTS	100 YEARLY EVENTS
• Road passable • No inundation (but high-tide flooding of property will increase with frequency and potential magnitude with sea level rise) • Ongoing coastal retreat resulting in increasing length of road being exposed and ongoing permanent damage to the road	• Road mostly passable (although may affect cars) • Debris to be removed • 2 homes destroyed, 4 with major damage, 5 with minor damage, 7 affected (2008 report) • Minor road repair costs along seaward edge of road/ pavement along exposed sections • Ongoing coastal retreat • Some loss of earnings	• Significant damage (assume 25%) along seaward edge of road along exposed sections, damage to pavement and potential breaching of the road • Potential for Utwe to be cut off for a short period of time until road is made passable (or is passable only on lower parts of the tide until road is fully repaired). • Debris to be removed • 25 homes located seaward of the road expected to sustain major damage • 73 located behind the road expected to sustain minor impact • Road repair costs • Ongoing coastal retreat / breaching of berm • Increased loss of earnings	• Significant damage (assume 60%) along seaward edge of road along exposed sections, damage to pavement and complete loss of road sections due to multiple road breaches • Potential for road access and power to Utwe to be cut off for a substantial length of time • Debris to be removed • 25 homes located seaward of the road expected to be completely destroyed • 73 located behind the road expected to sustain major impact • Road repair costs • Ongoing coastal retreat/ breaching of berm • Increased loss of earnings

In total, 70 household representatives provided data at the community consultations. Those who completed the questionnaires provided basic data on negative impacts from over-wash such as impacts on power, access to work and schools as well as impacts on home gardens. As an example:

- 10 per cent of all household respondents have spent time to clear yards and or homes of debris. On average, respondents reported spending six days on clean-up;
- 23 per cent of all household respondents stated that power was interrupted as a result of inundation. On average, the outage lasted for three days; and
- 10 per cent of respondents reported losing income due to road blockages, power outages, clean-up, or other inconveniences from the over-wash. The average earnings lost was three days' worth.

Considering that the minimum hourly wage for employment with the national government in Kosrae is USD 1.42 per hour, or approximately USDD 10 for a seven hour day (Bureau of Democracy, Human Rights, and Labour 2010), the diversion of time to clean up and or loss of income is noteworthy.

Extrapolating the survey data to estimate community costs from such effects presumes that the sample of community representatives completing the questionnaire are statistically representative of the entire community affected. This is not certain at this point. Nevertheless, at the explicit request of SPREP, cost estimates for power loss and interrupted earnings are estimated in this analysis using this approach. While they will certainly indicate the social harm from over-wash increasingly faced by the coastal community, the numbers, while modest, must nevertheless be treated with caution.

Lost earnings were estimated by multiplying the average days lost of work in the community by the minimum wage rate. Because some of these individuals lost earnings due to time spent cleaning-up after an event, the cost of remaining clean-up activities was calculated separately (Table 11).

TABLE 11. LOST EARNINGS

REASON FOR LOSS	TOTAL DAYS LOST	HOUSEHOLDS AFFECTED	AVERAGE LOST	% SURVEY AFFECTED	# HOUSEHOLDS REPRESENTED BETWEEN MALEM AND UTWE
Clean up	8.0	4.0	2.0	5.7	5.6
Other	9.0	3.0	3.0	4.3	4.2
Total	17.0	7.0	2.4	10.0	9.8

For 1:40 and 1:100 year events, there was little frame of reference to estimate probable higher impacts upon earnings. As a result, an illustrative increase of costs of 100 per cent was applied for a 1:40 year event and an increase of 400 per cent for a 1:100 year event for indicative purposes.

Summary findings from the community consultations and questionnaire are provided in Annex 1.

3.7 Existing coastal erosion rates

The coastal area between Malem and Utwe is subject to coastal erosion and the retreat of land. According to KIRMA, aerial imagery analysis by SOPAC and KIRMA reveals that land loss between Utwe and Malem has varied over time with:

- approximately 45 to 50 metres lost to erosion between 1944 and 1976;
- approximately 15 to 19 metres lost from 1976 to 1997; and
- approximately 5 to 17 metres lost from 2000 to 2014.

If nothing changes, the coast line would continue to retreat over time because of erosion. Some adaptation options would be expected to affect this change (for instance, revetment would stop coastal retreat), while others would not (such as an inland road).

Based on the figures presented, KIRMA estimates that average historic land loss is approximately 0.8 m^2 per year (Blair Charley, KIRMA, personal communication, October 2015). This figure was used to quantify the value of different adaptation options in reducing coastal retreat (if any). Bearing in mind that the average value provided by KIRMA reflects historic coastal change over a long period of time, this average is assumed to reflect the impact on coastal retreat of a variety of over-wash events, including those with damaging waves (such as a cyclone).

3.8 Impacts of adaptation options on over-wash/ inundation impacts

The absence of baseline recorded data on over-wash events and the fact that the detailed designs of adaptation options will only be finalised during project implementation means that the effect of the options on present trends in over-wash costs cannot be known with certainty. Nevertheless, based on the information presented so far and discussion, some logical deductions can be made about the form of change on the community: principally, that damages to homes will be reduced from destruction to major damage, or major damage to minor damage, or minor damage to affected, and so on.

Road repairs using an upgraded road are assumed to be avoided for smaller over-wash events of 1:5 and 1:40 year recurrences. For larger 1:100 year events, the effectiveness of adaptation options in mitigating damage varies according to the technology. Road repairs for an upgraded road are assumed to fall for 1:40 and 1:100 year events. In the absence of reports or experience by government officials, indicative savings in road repairs for 1:40 and 1:100 year events are assumed at 50 per cent.

Based on consultations with Kosrae State Government officials and NIWA, the assumed impacts of alternative adaptation options used in the analysis are presented in Table 12.

TABLE 12. IMPACTS ON OVER-WASH ASSUMED FOR OPTIONS

	MINOR EVENTS	5 YEARLY EVENTS	40 YEARLY EVENTS	100 YEARLY EVENTS
Status quo (no change)	• Road passable • No inundation • Ongoing coastal retreat	• Road mostly passable (although may affect cars) • Debris to be removed • 2 homes destroyed, 4 with major damage,5 with minor damage, 7 affected (2008 report) • Minor road repair costs • Ongoing coastal retreat • Some loss of earnings	• Some breaching of the road • Debris to be removed • 25 homes located seaward of the road expected to sustain major damage • 73 located behind the road expected to sustain minor impact • Road repair costs • Ongoing coastal retreat • Increased loss of earnings	• Multiple road breaches • Debris to be removed • 25 homes located seaward of the road expected to be completely destroyed • 73 located behind the road expected to sustain major impact • Road repair costs • Ongoing coastal retreat • Increased loss of earnings
Entire road revetment and new coastal road to existing specifications	• Road passable • No inundation • No coastal retreat	• Road passable (although may affect cars) • Debris to be removed • Ongoing harm to houses • Ongoing minor road repair costs • No coastal retreat • Some loss of earnings	• Road breaches continue • Debris to be removed • 25 homes located seaward of the road continuing to sustain 'major damage' • 73 located behind the road continuing to sustain 'minor impact' • Ongoing road repair costs • No coastal retreat • Increased loss of earnings	• Road breaches • Debris to be removed • 25 homes located seaward of the road continuing to be completely destroyed • 73 located behind the road continuing to sustain major impact • Ongoing road repair costs • No coastal retreat • Increased loss of earnings
Road upgrade (elevated) with selective revetment	• Road passable • No inundation • No coastal retreat	• Road passable • No debris removal costs • Compared to 2008, no homes impacted • No road repair costs • No coastal retreat • No loss of earnings	• No road breaches/ debris removal costs • 25 homes located seaward of the road continuing to sustain 'major damage' • 73 located landward of the road go from 'minor damage' to 'affected' • Road repair costs reduced by 50 per cent • No coastal retreat • Loss of earnings reduced by 50 per cent	• Road breaches now avoided • Debris on road reduced by 50 per cent • 25 houses located seaside of the road contuse to be completely destroyed • 73 houses located landward of the road go from major damage to 'minor' • Road repair costs reduced by 50 per cent • No coastal retreat • Loss of earnings reduced by 50 per cent
Inland road with selective revetment	• Road passable • No inundation • Ongoing coastal retreat	• Road passable • No debris removal costs • No road repair costs* • Gradual reductions in inundation with relocation • (Ongoing coastal road damage)* • No coastal retreat • No loss of earnings	• No road breaches/debris removal • No road repair costs* • Gradual reductions in inundation with relocation • (Ongoing coastal road damage)* • No coastal retreat • No loss of earnings	• No road breaches/ debris removal • No road repair costs* • Gradual reductions in inundation with relocation • (Ongoing coastal road damage)* • No coastal retreat • No loss of earnings

Sources: Blair Charley, KIRMA; Lipar George, ODA; Nena M. William, Office of the Governor, Kosrae State; and Leandro Olando, Civil Engineer, Department of Transport and Infrastructure, personal communication, October 2015

** Any retention of the coastal road while the inland road exists would require ongoing maintenance and repairs in the interim*

POSSIBLE RATES OF RELOCATION

A key objective in the road relocation project is to facilitate the relocation of the communities at risk in Malem to Utwe of coastal over-wash and inundation, especially in the face of ongoing sea level rise and climate change. Theoretically, establishment of an inland road would facilitate relocation from the threatened coastline and reduce the number of families and homes at risk of over-wash, reducing the costs of over-wash events. At present, the rate of relocation from the villages or coast to the interior is entirely hypothetical—no relocation strategy has been devised. Relocation would be affected by a variety of factors, not least of which is ownership of or access to land in the interior for building as well as access to finance to support the establishment of new housing.

Based on consultations with the communities concerned (Annex 2), community members are completely in favour of relocating because the threat of coastal inundation and harm to person security, health, and well-being is high. However, until it is clear what kind of assistance would be available to assist relocation, the ability of families to relocate is uncertain. Discussions were held with government representatives, some of whom are based in the affected communities, to consider potential scenarios for relocation, should an inland road be established. Based on these discussions together with discussions with the State Government of Kosrae (Lipar George, personal communication, October 2015), a *conservative* base case relocation rate was estimated in which two householders relocate every five years *following the completion* of the road. This would result in an average relocation over fifty years of 18 households (18 per cent).

DT&I add that if relocation of the community away from the hazardous area is slow (less than five households every five years, starting five years after completion of the road), the present access roads would not likely be adequate to provide transport connections for all families still in the process of relocating away from the coastal hazard zone after 20 years (Buncle 2015). As a result, the existing coastal road would have to be replaced after 20 years. This analysis then includes replacement of the entire existing coastal road after 20 years so slow migration levels.

AGRICULTURAL IMPACTS OF OPENING UP THE INTERIOR

The State Government of Kosrae observes that agriculture production was undertaken by the Japanese in the Malem and Utwe areas during World War II. Aerial imagery indicates that approximately 160 acres were farmed at the time (Blair KIRMA personal communication; Figure 7). However, agricultural activity in the area ceased following the removal of the Japanese from the island. Drawing on the experience provided, the State Government of Kosrae consider that once access to the interior is facilitated and agriculture is able to develop, this same scale of agricultural could be targeted again in the future for subsistence or commercial harvesting purposes (Buncle 2015).

Department of Agriculture officials suggest that tangerine would be a representative/typical crop type for future inland production. Department of Agriculture representatives proposed average expected annual yields of approximately 2,400 pounds of fruit per acre (Remos Livaie, Agriculture Division, Department of Resources and Economic Affairs, personal communication, November 2015).

Discussions with government representatives (Blair Charley, KIRMA; Nena M. William, Office of the Governor, Kosrae State, Remos Livaie, Agriculture Division, DREA) were used to identify a scenario where increasing areas of land (10 acres extra per year) gradually transfer over to tangerine agriculture until the area formerly used by the Japanese for agriculture is filled. Price information to determine the potential value of this new agricultural production was obtained from local market survey (USD 0.55 per pound) and from export monitoring datasheets (USD 0.50 per pound at quarantine in 2012).

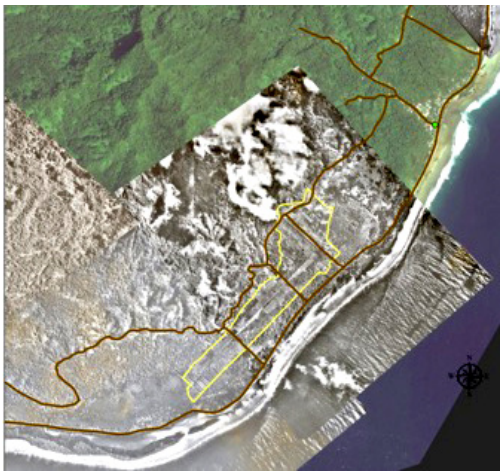


FIGURE 7. 1944 CULTIVATED AREAS FROM MALEM TO UTWE. SOURCE. BLAIR CHARLEY

A summary of values estimated and their importance to the overall picture of adaptation are provided in Table 13.

TABLE 13. VALUES ESTIMATED

IMPACT	VALUED?	COMMENT
Debris blocking the road and cost to remove	Yes	
Inundation of coastal houses	Yes	These values are indicative. Actual values are likely to be significant since repeated events would undermine the structural integrity of homes and also potentially result in damage to possessions
Damage to cars	No	
Damage to garden crops	No	
Inability to get to work (Utwe and Malem) resulting in lost income	Yes	Likely to be important to the community as the government is the key employer and average incomes are low
Inability to reach schools and hospitals	No	Important from the perspective of decreasing poverty
Interruption of power, telecommunications – inconvenience for households, loss of earnings to utilities	No	Important – power outages were the utility most commonly noted by community representatives power as a result of over-wash (almost a quarter of all respondents reported interruptions to power as a result of inundation.)
Damage to road and need for repairs	Yes	
Trauma and inconvenience	No	
Limited access to interior	No	This is a significant benefit that would affect generations into the future
Road maintenance	Yes	KIRMA (2014)
Land Acquisition	Yes	
Road and utility construction	Yes	
Maintenance of new and existing	Yes	
Awareness cost	Yes	
Environmental impacts?	No	

4. Preliminary Results and Sensitivity Analysis

In the first instance, different adaptation options are assessed for their value:

- In comparison to a *status quo* situation in which the coastal road is replaced, with replacement of the road occurring in the first two years;
- Using a four per cent discount rate;
- Assuming that relocation of the coastal community as a result of opening up the interior of the island through a new inland road occurs at a conservative rate of two households moving every five years, starting five years *after* the road has been completed;
- Assuming that this conservative rate of relocation away from the coastal area would require replacement of the existing road after 20 years, if the option continues after 2035, to support families who remain in the area and who relocate slowly;
- Assuming that there is no increase in the number of developments of the coastal area unless otherwise stated; and
- Assuming that revetment of critical parts of the coastline will proceed regardless of delays in adaptation.

As indicated in Sections 2 and Table 13, not all benefits or costs from an adaptation option may be readily identified in practice. In such cases, these values are considered qualitatively, and their significance is discussed in detail in the Implications Section. In this analysis, some critical values were not quantified. These values include the benefit of adaptation to smaller over-wash events (not just the 1:5 year, 1:40 year, and 1:100 year events), and the benefits over the next 50 years, and to future generations, of access to the interior of Kosrae for both safe harbour and for economic development. Because omitting values from a CBA is not ideal, interpreting the findings of this CBA must be conducted responsibly. Accordingly, readers are reminded that CBA numbers only tell part of the story about the merits of adaptation; the other part of the story lies in the Implications Section where those items not valued are described and what this means for the overall merit of the activities and their design are considered.

Detailed findings of the quantified analysis can be found in Annex 5 with a summary of the key findings presented here and in Section 6. Summarised values are presented in Table 14 which displays the estimated and payoffs of alternative adaptation options as far as they could be quantified in the form of:

- net benefits of the adaptation option after costs over time have been accounted for. This is referred to as the net present value of the option or NPV; and
- the payoff per dollar invested in each option. This is the value benefits of the option in terms of each dollar infested: the benefit:cost ratio or BCR.

Based on data available, establishing an inland road network now offers the highest quantified NPV over a 50 year period (Table 14). This option offers an NPV of USD 0.37 million. This is equivalent to a payoff per dollar (BCR) of 1.05. In other words, for every dollar invested in an inland road, the people of Kosrae gain back USD 1.05 in savings[4].

Establishing the road in the future offers lower net payoffs than establishing it sooner as a result of the effect of delaying benefit flows. The BCR for establishing the inland road in ten years and in 20 years is 0.91 and 0.96 respectively.

It is important to highlight here that, as indicated in Table 13, many of the critical benefits for the inland road options have not been quantified in this analysis. First, benefits from avoiding small-scale over-wash events, from opening up the interior, and from avoiding damage to possessions, amenities, etc., are not included, which means that the value of an inland road now (as well as in the future) is underestimated.

4 Quantified savings; some benefits were not quantified. See Table 13.

Moreover, considering the ongoing nature of sea level rise, the long-term benefits of opened access to the hinterland by an inland road is a benefit that would be experienced for generations to come. In addition, and as indicated in Section 2.6, the benefits of an inland road today (as well as in the future) will likely be felt for many more smaller over-wash events than just the three types used to quantify benefits. As a result, the true benefits of road relocation now and in the future are certainly much higher.

Based on data available, the option to upgrade the existing coastal road is not expected to generate a positive net benefit. This option offers a quantified NPV of USD –0.85 million, or a BCR of 0.86 (that is, USD 0.86 in savings/ benefits per USD 1 invested).

TABLE 14. QUANTIFIED PAYOFFS (FOUR PER CENT DISCOUNT RATES[5]). ASSUMES RELOCATION FOLLOWING COMPLETION ON AN INLAND ROAD OF TWO HOUSEHOLDS EVERY FIVE YEARS. RANKING 1 IS BEST

		REVETMENT WITH COASTAL ROAD REPLACED TO EXISTING SPECIFICATIONS	COASTAL ROAD UPGRADED (ELEVATED)	INLAND ROAD FROM 2017				CONSTRUCTION OF INLAND ROAD IN 10 YEARS' TIME (2026)	CONSTRUCTION OF INLAND ROAD IN 20 YEARS' TIME (2036)
				No maintenance of old road	10 years maintenance of old road	20 years maintenance of old road	50 years maintenance of old road)		
NPV	Value	–2156561	–849020	387330	380785	371039	–1767740	–556570	–225349
	Rank	8	6	1	2	3	7	5	4
BCR	Value	0.58	0.86	1.06	1.06	1.05	0.94	0.91	0.96
	Rank	8	7	1	1	3	5	6	4

IMPACT OF MAINTAINING THE OLD ROAD OF THE VALUE OF A NEW INLAND ROAD

The payoffs of establishing a new inland road network were scrutinised if the old coastal road was maintained for various periods (not maintained, or maintained for 10, 20, or 50 years). In these cases, the benefits from establishing the road remain much the same, while the costs slightly increase. Nevertheless, the costs of road maintenance are not high, and these costs are diminished with time, with the effect that the impact on payoffs is negligible, provided that maintenance does not extend beyond 20 years. Maintaining the existing coastal road does, however, have an impact if the road is maintained for 50 years because, as indicated in Section 3.1 (Baseline data – Costs associated with the existing road), maintenance of the existing road after 20 years would require a major replacement of the existing road after 20 years (Table 14). This is discussed further in the Sensitivity Analysis under *Speed of relocation* below. At this point, the value of avoiding having to replace the existing road (say, by speeding up migration) or investing in other adaptations might be considered.

4.1 Sensitivity analysis

The biggest uncertainties in valuing the road project particularly are:

- costs for the road;
- the discount rate;
- the frequency of severe weather events (direct hits by a tropical cyclone);
- the degree to which it facilities relocating of families away from the threatened coastline and into the interior (or elsewhere for that matter) of Kosrae; and
- the availability of funding for the entire proposed road project. If funding is not accessed, this may affect implementation of the proposed road network.

These matters were subjected to a sensitivity analysis.

5 The Kosrae State Government does not have an official discount rate. In the absence of such an official discount rate, a 4% rate is used. The rationale for selecting this rate is that it represents the average worldwide real interest rate over the last 150 years (Mankiw 2007). Moreover, a 4% discount rate has been used in other CBA studies recently completed for Kosrae, and applying the same discount rate here will provide for easier comparison and prioritisation of investments within Kosrae.

COSTS FOR THE ROAD

The costs to establish an inland road network were first estimated by KIRMA (2014) and then updated by DT&I. These costs therefore represent the most up to date figures for the State Government of Kosrae. The island is reliant upon imports and, as a small island state, is subject to the fluctuations of the international market. To account for the possibility that imported materials might increase in price and consider their impacts upon the value of an inland road, a sensitivity analysis was conducted in which the cost of constructing the road increased by ten per cent.

In this case, the quantified net costs of an inland road network established today are somewhat sensitive to costs. An increase of ten per cent in construction costs results in a net cost of approximately USD –0.16 million, or a payoff of 0.98, that is, USD 0.98 worth of benefits per dollar invested (Table 15). This does not change the ranking of the inland road network relative to other adaptation options.

TABLE 15. QUANTIFIED PAYOFFS WITH HIGHER CONSTRUCTION COSTS (FOUR PER CENT DISCOUNT RATES). ASSUMES RELOCATION FOLLOWING COMPLETION ON AN INLAND ROAD OF TWO HOUSEHOLDS EVERY FIVE YEARS

	INLAND ROAD FROM 2017 (MAINTENANCE OF OLD ROAD FOR 20 YEARS)	INLAND ROAD FROM 2017 OLD ROAD ABANDONED, COSTS 10% HIGHER
NPV	371,039	-159,395
BCR	1.05	0.98

DISCOUNT RATE

The State Government of Kosrae does not have a preferred discount rate for investment analysis. In the absence of this preferred rate, the base case to appraise options involves a four per cent discount rate to consider the economic impact of time on impacts. The rationale for selecting this rate is that it represents the average worldwide real interest rate over the last 150 years (Mankiw *Macroeconomics* 2007). Moreover, a four per cent discount rate has been used in other CBA studies recently completed for Kosrae, and applying the same discount rate here will provide for easier comparison and hence prioritisation of investments within Kosrae.

In practice, the results in this analysis are sensitive to the discount rate used. Lower discount rates generally improve the quantified payoffs for adaptation because they assign greater importance to future benefit flows (Table 16). As a result, with a discount rate of zero per cent, an inland road established today is shown to generate a significantly higher pay off (NPV = 8,842,563; BCR = 2.23) provided that maintenance of the existing coastal road does not exceed 20 years (because this requires a new replacement of the existing coastal road).

In contrast, a higher discount rate reduces the quantified payoffs for adaptation because they assign less importance to future benefit flows (Table 16). As a result, with a discount rate of ten per cent, an inland road established today is shown to generate a negative pay off (NPV = USD –2,086,839; BCR = 0.67) and delaying the construction of the road becomes the highest-ranked option. Again, it is emphasised that a number of important benefit categories are not reflected in the quantitative results due to a lack of data.

TABLE 16. QUANTIFIED PAYOFFS WITH DIFFERENT DISCOUNT RATES. ASSUMES RELOCATION FOLLOWING COMPLETION ON AN INLAND ROAD OF TWO HOUSEHOLDS EVERY FIVE YEARS. RANKING 1 IS BEST

DISCOUNT RATE		REVETMENT WITH COASTAL ROAD REPLACED TO EXISTING SPECIFICATIONS	COASTAL ROAD UPGRADED (ELEVATED)	INLAND ROAD ESTABLISHED TODAY				CONSTRUCTION OF INLAND ROAD IN 10 YEARS' TIME (2026)	CONSTRUCTION OF INLAND ROAD IN 20 YEARS' TIME (2036)
				No maintenance of old road	10 years maintenance of old road	20 years maintenance of old road	50 years maintenance of old road)		
10	NPV	–1325868	–2161309	–2074635	–2082481	–2086839	–5251561	200982	1259470
	Rank	3	7	4	5	6	8	2	3
	BCR	0.69	0.64	0.67	0.67	0.67	0.66	1.06	1.58
	Rank	3	8	4	4	6	7	2	3
4	NPV	–2156561	–849020	387330	380785	371039	–1767740	–556570	–2156561
	Rank	8	6	1	2	3	7	5	8
	BCR	0.58	0.86	1.06	1.06	1.05	0.94	0.91	0.58
	Rank	8	7	1	1	3	5	6	8
0	NPV	–4371735	3522576	8858529	8859954	8842563	5407040	2724143	–158169
	Rank	8	6	1	2	3	7	5	4
	BCR	0.44	1.55	2.24	2.24	2.23	1.51	1.26	0.99
	Rank	8	7	1	1	3	5	6	4

FREQUENCY OF SEVERE WEATHER EVENTS

Consultations conducted between SPREP and the State Government of Kosrae reveal that there is some uncertainty around how often tropical cyclones will directly hit Kosrae in the future. The base case for this analysis assumes that a direct hit can be expected approximately every 100 years (Table 5), although this could be as regular as every 75 years (Buncle 2015).

Based on the data available, the findings are not sensitive to changes in assumptions about the return frequencies of direct tropical cyclone hits. If a direct hit was sustained every 75 years instead of just every 100 years, the payoffs and ranks for adaptation options remain virtually the same (Table 17).

TABLE 17. QUANTIFIED PAYOFFS WITH MORE FREQUENT DIRECT CYCLONE HITS (4 PER CENT DISCOUNT RATES). ASSUMES RELOCATION FOLLOWING COMPLETION ON AN INLAND ROAD OF TWO HOUSEHOLDS EVERY FIVE YEARS. RANKING 1 IS BEST

DISCOUNT RATE		REVETMENT WITH COASTAL ROAD REPLACED TO EXISTING SPECIFICATIONS	COASTAL ROAD UPGRADED (ELEVATED)	INLAND ROAD ESTABLISHED TODAY				CONSTRUCTION OF INLAND ROAD IN 10 YEARS' TIME (2026)	CONSTRUCTION OF INLAND ROAD IN 20 YEARS' TIME (2036)
				No maintenance of old road	10 years maintenance of old road	20 years maintenance of old road	50 years maintenance of old road)		
NPV	Value	–2232538	–827679	432137	425591	415846	–1678126	–531542	–211737
	Rank	8	6	1	2	3	7	5	4
BCR	Value	0.56	0.87	1.06	1.06	1.06	0.95	0.92	0.96
	Rank	8	7	1	1	3	5	6	4

SPEED OF RELOCATION

The base case to value the inland road was that five years after the road is completed, two households would relocate every five years to the interior. This estimate is potentially conservative considering that:

- some of the families along the threatened coastline already own land in the interior around the proposed road;
- the community have expressed absolute commitment to relocating inland; and
- consultations undertaken in the preparation of the proposal, in particular, with landowners, show full support for the development into their land (SPREP 2015b).

In light of this, a sensitivity analysis has been conducted to assess the potential quantified payoff from the road with a faster relocation. In this case, the payoff has been assessed assuming two alternative faster payoff scenarios:

- that five households move every five years, starting five years after road completion; and
- that one household moves every two years, starting two years after road completion.

Community consultations (Annex 2) confirm that the ability of the community to relocate hinges upon a number of factors including:

- access to land: not all families own land in the interior near the proposed inland road; and
- access to finances: as noted in Section 2.6, an average house in Kosrae has a replacement value of approximately USD 43,000. Few family members have access to such money to establish a new house once an inland road is established. Frankly, they would likely need some form of financial assistance to be able to take up the opportunity provided through an inland road to move.

As can be seen from Table 18, the quantified payoffs from an inland road are not very sensitive to relocation rates. This is likely because the assumed transition of families to the interior is so gradual that, once discounting is taken into effect, there is little impact on the present value of benefits. A more rapid rate of relocation improves the NPV of establishing a new inland road, but not by much.

TABLE 18. INLAND ROAD FROM 2017* WITH DIFFERENT RELOCATION RATES (4% DISCOUNT RATE)

	MOST LIKELY?	FASTER RELOCATION?
	2 HH move every 5 years starting 5 years after establishment	5 HH move every 5 years starting 5 years after establishment
NPV	371,039	645,958
BCR	1.05	1.10

** Established 2017, no maintenance of coastal road*

A more important change arises under a scenario where the existing coastal road needs to be re-instated[6] because of slow migration. The expenses associated with establishing an inland road climb substantially if the existing coastal road has to be retained for more than 20 years (Table 19).

A clear lesson from this is that any inland road strategy should, if practical, seek to avoid having to maintain the existing coastal road for over 20 years. For example, government might want to develop a strategy to facilitate rapid migration over a 20 year period to avoid having to replace the old coastal road in the long term.

6 i.e. replaced due to substantial degradation.

TABLE 19. BENEFITS FROM SPEEDIER RELOCATION. THE CASE OF MAINTAINING THE COASTAL ROAD FOR 50 YEARS (FOUR PER CENT DISCOUNT RATE)

	INLAND ROAD FROM 2017 (OLD ROAD MAINTAINED FOR 50 YEARS; 2 HOUSEHOLDS MOVE EVERY 5 YEARS; COASTAL ROAD REPLACEMENT)	INLAND ROAD (OLD ROAD MAINTAINED FOR 50 YEARS; NO ROAD REPLACEMENT (DISPLAYS SAVINGS OF FASTER MIGRATION)
NPV	–1,767,740	360,170
BCR	0.94	1.05

TARGETTING THE MALEM-YESENG PORTION OF THE INLAND ROAD ONLY

At the request of SPREP, an estimate was made to assess the potential value of establishing the inland road network connecting only Malem to Yeseng. This option becomes important if only part of the funding for the road project becomes available in the first instance. This raises the question of the kind of benefits that staged road relocation might offer Kosrae state.

Targeting the Malem to Yeseng component of the proposed inland road network involves upgrading the two existing access roads as well as establishing a short portion of the inland road (approximately 39 per cent of the costs of the entire proposed road network from Malem to Utwe). To estimate the impact of inundation events occurring with a return frequency of every five, 40, and 100 years:

- it is assumed that construction of this partial road network takes one year, compared to two years for the entire proposed Malem and Utwe inland road network;
- the portion of the coast not covered by an inland road—Yeseng to Utwe—would still require road replacement;
- the proportion of the Malem-Utwe coastline covered by Malem to Yeseng was used to attribute:
- its share of the road replacement costs;
- its share of estimated road clean-up and repair costs in the event of over-wash; and
- its share of old road maintenance applicable to that small road area;
- the proportion of Malem-Utwe households represented over Malem to Yeseng was used to attribute its share of agricultural production facilitated in the interior;
- the maintenance costs of the new shorter inland road are estimated at two per cent of total construction costs, annualised over 50 years;
- the distribution of damage to housing from 1:5, 1:40, and 1:100 year events along the Malem-Utwe coastline was applied to the Malem-Yeseng stretch of coastline, and then scaled down according to the proportion of houses represented in the Malem-Yeseng portion; and
- it is assumed that coastal harm will continue unimpeded to be experienced along the Yeseng-Utwe stretch of the coast.

With a four per cent discount rate, a partial road from Malem to Yeseng is estimated to generate a net cost of approximately USD –6.6 million, offering a lower per dollar invested payoff than a full inland road network established now and in the future. The limited payoff represents the fact that a smaller proportion of families would benefit from the road while the government would still have to replace the existing coastal road to support those families who do not benefit as well as to cope with slow migration.

5. Equity and Distributional Implications

Stakeholders experiencing the benefits of a new road are divided between the private sector (principally residents of Utwe and Malem) and the public sector (government departments responsible for repairs to the existing coastal road and clean up following an over-wash event) (Table 20).

Based on the 2010 census, which is the latest on hand, householders in Utwe and Malem who stand to benefit from the new road are at the lowest spectrum in terms of socioeconomic status, compared with the people of Lelu and Tafunsak. The 2010 census shows the average income for the people of Utwe at USD 7,833 and 11,745 for Malem, while Lelu and Tafunsak stand at USD 14,065 and 13,159, respectively. The costs of lost earnings from road blocks to these families is therefore likely to be more harshly felt than in more affluent communities. Lost education effects are also likely to be important in the longer term because education is essential for development opportunities. Additionally, community consultations revealed that over-wash commonly harmed subsistence crops of families. In view of the limited income of the families concerned, ongoing or worsening loss of food crops as a result of over-wash will logically be felt more keenly by this community.

Ongoing impacts of road cut offs, lost food, and lost education opportunities associated with over-wash will harm the economic resilience of an already disadvantaged community. The proposed new road would thus be expected to contribute positively to improved equity within the Kosraean community by minimising lost present and future earnings and improving long-term food security.

The benefits of the new road are expected to be felt primarily by families, principally through access to increased agricultural production opportunities. This is significant because it implies both a potential increase in food security to an isolated but also the potential increase in income/saving in food purchases for a less-privileged community. Nevertheless, it is possible that other unanticipated impacts may also arise from the new road (such as environmental impacts), although this is not clear because no environmental impact assessment has yet been undertaken. Certain impacts will be felt by more specific groups.

TABLE 20. POTENTIAL STAKEHOLDERS IN THE ROAD PROJECT

COST/BENEFIT	STAKEHOLDER	COMMENTS
Debris blocking the road and cost to remove	DT&I	
Inundation of coastal houses	Householders (Utwe, Malem)	
Damage to cars	Householders (Utwe, Malem) School buses General public	
Damage to garden crops	Householders (Utwe, Malem)	All household members take care of garden; there is no perceived burden on one particular group of society
Inability to get to work (Utwe and Malem) resulting in lost income	Householders (Utwe, Malem)	
Inability to reach schools and hospitals	Householders (Utwe, Malem)	Estimated at >300 students (School year 2014 Enrolment, Kosrae Statistics Office)
Interruption to power/ telecommunications – inconvenience for households	Householders (Utwe, Malem)	
Interruption to power, telecommunications – loss of revenue to utilities	Utilities (public sector)	
Standard maintenance of old road	DT&I	
Repairs to the road following over-wash events	DT&I	
Trauma and inconvenience	Householders (Utwe, Malem)	
Limited access to interior	Land owners	
Land Acquisition	Government	
Road and utility construction	Government	
Maintenance of new road	Government	
Awareness campaign	Government	

TABLE 21. POPULATION OF MALEM AND UTWE

VILLAGE	MALE	FEMALE	TOTAL
Malem	257	236	493
Utwe	458	525	983
TOTAL	**715**	**761**	**1476**
% of total	*48*	*52*	*100*

6. Implications

A number of options exist for the coastal communities of Malem and Utwe to adapt to climate change. The form of that these options could take can vary. For example, revetment could cover the entire coastline or just parts. New coastal roads could be built to existing design standards or to new design standards. This analysis considers selected adaptation options to consider a way forward for Kosrae. In so doing, the analysis provides conservative estimates of the potential payoffs from the adaptation options.

The values are conservative because:

- the analysis is based on the quantified benefits from the different adaptation options arising from only three types of events: 1:5 year events, 1:40 year events, and 1:100 year over-wash events. However, the adaptation options could also generate benefits when other events occur;
- some benefits of adaptation—avoided injuries/fatalities arising from severe events, avoided damage to cars and crops or ongoing access to schooling—have not been quantified. Significantly, the calculations are based on the assumption that only families located around the coastal road from Malem to Utwe relocate over time with improved access to the interior via a new inland road. In practice, relocation might not be restricted to these communities. Families from other parts of Kosrae might also benefit from improved access to the interior through relocating or using their own inland sites for agriculture production; and
- by opening up access to the interior of Kosrae, facilitating enhanced agricultural production while changing the dynamic of development away from the hazardous coastline and into the safer and more sustainable interior, the road could be expected to benefit communities beyond the 50 year period of this analysis, benefitting the community for generations to come.

As a result of these three issues, the potential benefits from developing an inland road now or in the future are quite certain to be higher than quantified.

Based only on those benefits quantified over a 50 year period and applying a four per cent discount rate, building the road now is shown to generate the highest payoff (NPV) of USD 0.37 million.

This is shown to be higher than establishing the inland road ten years in the future (NPV = USD –0.56 million) and 20 years in the future (NPV = USD –0.23 million), reflecting, in part, the increasing risks presented by sea-level rise and (potentially also) cyclones.

The option to establish the inland road now is also shown to be superior to the alternative course of action: to protect or upgrade the existing coastal road. These options were shown to generate a negative payoff (NPV = USD –2.16 million and USD –0.85 million respectively). Moreover, there are a number of important limitations associated with these responses that are not fully captured in the aggregate results. Most importantly:

- the benefits of an upgraded coastal road specifically would only accrue to those families located *landward* of the road who would benefit from reduced inundation. In contrast, families located *seaward* of the upgraded road would remain in the direct line of the waves and continue to be affected by over-wash, with potential harm to family members or properties worsening over time as the sea level rises. As a result, these families would eventually still have to find an alternative means to adapt to the coastal threats. In community consultations, families in Malem and Utwe stated firmly that if the coastal threats are not addressed, the area will cease to be a safe and sustainable place for them to inhabit. They viewed that migration out of Kosrae or FSM is the only option remaining (Annex 2). Considering that Kosrae already represents the smallest state in FSM and that the island is presently experiencing a net loss of population due to outward migration (Division of Statistics undated), increased migration as a result of coastal threats may not be desirable both in terms of economic potential and in terms of retaining Kosrean culture.

- protecting or upgrading the coastal road can risk generating a false sense of security in the community, allowing families to believe that the area is now safe from inundation and *implicitly encouraging* further coastal development. Such an option is therefore counter to the State development plan intent of encouraging inland development because it can hamper relocation in the medium term. In contrast, establishing an inland road network facilitates relocation and opening up the interior; and
- there are likely to be additional environmental costs of establishing construction work such as protecting or upgrading of the road along the coast (such as downstream erosion). In the face of ongoing sea level rise, this would appear to be unwise.

There are also other considerations. The payoffs for an inland road established today appear to be sensitive to assumptions about the discount rate. If the discount rate is ten per cent, the quantified payoffs for an inland road established today become negative, but payoffs when delaying construction for ten or 20 years still remain positive. The issue of discount rate is important because discussions with State Government of Kosrae officials (Buncle 2015) reveal that while the government does not have a preferred discount rate, some departments consider that a discount rate of 4% is more appropriate than a higher rate of approximately 10%. Among other considerations, this is because inter-generational equity is a major consideration in Kosrae culture.

Because some of the unquantified payoffs from an inland road network—particularly in terms of lives and safety ensured and food security increased—are likely to be significant (see Table 12), it is reasonable to expect that the NPV for establishing an inland road system is actually higher. Considering (i) that it will take time for the community to relocate away from the coast and (ii) that an upgraded coastal road would likely *encourage* development in a hazardous area, risking lives and well-being, there would appear to be sense in targeting the establishment of an inland road now, rather than waiting for the future. This suggests the need for a long planning period for relocation (both in general, as well as with the road specifically). Consequently, long-term government commitment to this would be essential. Moreover, government might want to develop a strategy to facilitate rapid migration over a 20 year period to avoid having to replace the old coastal road in the long term because this generates considerable costs. In this respect, there would logically be value in conducting a strategic campaign to support community relocation to avoid existing coastal road replacement and gain the most benefits from an inland road network.

- The sensitivity analysis conducted in this study reveals that the quantified benefits of establishing a shortened road (from Malem, to Yeseng) are not positive and are lower than those that could be achieved by establishing a complete road. This likely reflects the fact that a smaller proportion of the community will benefit while ongoing treatment of the existing coastal road remains. Equally importantly, establishing a portion of the inland road from Malem to Yeseng will leave the community of Utwe cut off from the rest of the community if the road becomes unpassable in future over-wash events. This is important for two reasons.
- First, ongoing threats will continue to undermine quality of life in the village, risking health and damaging possessions. In particular, damage to the road takes time to repair. While ‘minor’ over-wash events may cut off families for one or two days, extreme events (such as a near cyclone) could cause extensive damage which could take from days to weeks to repair. Ongoing interruption to family life, earnings and education—especially in a community less advantaged than the rest of the Kosrae community—is important. Second, and as already indicated, the poor condition of the existing inland access roads brings into question the safety of the community in using these roads as escape routes. As a result, establishing a partial inland road does not address the quality of all the inland access and the immediate safety of the community. An advantage of establishing an entire inland road is rather that, should a sudden storm surge or over-wash event occurm families will all have immediate access to safe inland roads as an escape route while also having long-term access to the interior of the island for development or establishing new homes.

DISTRIBUTIONAL CONSIDERATIONS

Based on the quantitative analysis conducted, by far the greatest beneficiaries from the establishment of an inland road established today are families (compared to government), principally in the form of access to the interior of Kosrae to extend agricultural production. This is important because the communities of Utwe and Malem who stand to benefit first from the new road project already have the lowest average earnings in Kosrae, compared with communities in Lelu and Tafunsak. The opportunity to increase income and or food security through increased agricultural would directly improve the wellbeing of these families.

Moreover, these families already presently suffer a variety of harmful effects from over-wash, including reduced earnings (when access to work is hampered by road blocks), reduced educational opportunities (when access to school is hampered by road blocks) and reduced access to food (through the destruction of home gardens). The harmful impacts from these effects have a disproportional impact upon these communities because they already have the lowest average earnings in Kosrae, compared with communities in Lelu and Tafunsak. Ongoing over-wash can therefore increase the economic vulnerability of the community. By comparison, a continually accessible road will minimise this harm and facilitate change, increasing the economic resilience of the community. While items values were not valued in the analysis in theory at least, an inland road project would contribute positively to both the food security and economic security of the community.

RELOCATION CONSIDERATIONS

Consultations held with stakeholders from Malem and Utwe revealed resounding support for an inland road and for relocation to the interior for safety and security. This support has also been affirmed in the present draft of the proposal for the road project (SPREP 2015b).

However, the rate at which families can move in practice will not be known with any certainty until the community can work through key issues in collaboration with government and policy makers:

- Relocation is likely to take time. The analysis presumes that relocation will be gradual. During this time, families who have not yet moved will continue to need access to the wider Kosrae community through a functioning road. Data analysis suggests that the cost of maintaining the existing coastal road for a few years will have a negligible impact upon the payoffs of a road. In contrast, retaining a functional coastal road could act as a deterrent to relocation to safer ground and can implicitly discourage relocation. After 20 years, retention of the existing coastal road would require a new coastal road to be established, which is expensive. There would therefore be logic in establishing a new inland road network while advising the community of the cessation of existing road maintenance at a specific point in time (e.g. 20 years or less), providing them with reasonable lead time for their relocation while minimising costs.
- An average house in Kosrae has a replacement value of approximately USD 43,000 (Section 4.7). Few family members have access to such money to establish a new house once an inland road is established. However, with financial assistance, relocation could be rapid because the community are keen to relocate for safety's sake. As indicated in Section 5, faster relocation provides higher net benefits from relocation. There is therefore logic in the Kosrae State government reviewing access to housing loans or resources for relocation.
- Relocation from the hazardous coast is unlikely to happen while development continues unconstrained along the coast. In the face of sea level rise and climate change, it is unsustainable and unsafe for any new developments to be allowed to continue in hazardous areas such as the Malem to Utwe coastline. In the interest of public safety, no new developments should be permitted here. This constraint would then create a higher drive for developments in safer areas.

- Interim development in hazardous areas such as the Malem to Utwe coastline should be subject to appropriate building standards. In the face of sea level rise, ground level developments would appear to be unsound. Engineers in the State and or national government should be able to recommend clear standards which State government should actively enforce for the safety of the community.
- To support a new inland road and address the points raised above, a strategic communication campaign is required. This campaign should include messages such as why the old road will eventually not be maintained, why new developments along the coastline are not supported, how government can support families in relocation, and so on.
- Ultimately, and as indicated in SPREP (2015b), a relocation committee is needed to clarify relocation issues.

FOOD SECURITY CONSIDERATIONS

The largest component of quantified benefits from establishing an inland road from today is increased agricultural activity from opening up the interior of the island. At the same time, the impact most commonly reported from over-wash was loss of subsistence crops in existing home plots. The cost of lost crops was not quantified in this analysis. However, considering that home gardens provide a common source of food in Kosrae, and in view of the likelihood that a representative home includes at least three young dependents, the negative impact of coastal inundation on food security is likely to be increasingly significant over time.

According to the Office of Statistics, Budget and Economic Management (2009a), Kosrae exported approximately USD 1.2 million worth of agricultural products in 2012 (Table 22). The value of food imports into Kosrae specifically is not presently clear on government web sites, although it is apparent that food imports into FSM in total were approximately USD 58 million in 2012 (Office of Statistics, Budget and Economic Management (2009b) (Table 23). If Kosrae's share of that total was estimated according to its share of national population, Kosrae would be a net importer of food. Ongoing damage to food gardens harms food security for the affected communities and this is likely to worsen with time. Efforts to open up the interior for safe agricultural development would assist in this. There is likely to be benefit in the state Government of Kosrae accompanying any inland road project with a strategic campaign to encourage sustainable agricultural development, as a result.

TABLE 22. VALUE OF EXPORTS (FOB), FSM. VALUE (USD 1,000S)

MAJOR COMMODITY GROUPS	2008	2009	2010	2011	2012
Agricultural Produce	21	38	27	46	59
Marine Products	-	1	1	464	1,175
Other Products	-	-	-	-	-
TOTAL	**21**	**38**	**27**	**509**	**1,234**

Source: Office of Statistics, Budget and Economic Management (2009a)

TABLE 23. FOOD IMPORTS TO FSM (USD 10,000S)

DESCRIPTION	2008	2009	2010	2011	2012
Animals and animal products	7,182	9,727	9,915	11,126	12,490
Vegetable products	10,524	12,278	9,592	11,760	13,877
Animal or vegetable fats	930	920	708	856	1,107
Prepared foodstuff, beverages	27,924	29,594	26,234	29,925	30,593

Source: Office of Statistics, Budget and Economic Management (2009b)

OTHER ISSUES

A number of issues concerning the road relocation are uncertain. First, the impacts of climate change adaptation projects are unclear. What is the potential environmental impact of major construction work along the coast or inland? While major projects bring potential risks, they might also bring opportunities. Would opening up the interior of Kosrae provide access to cultural sites hitherto denied to the community because they could not access the area? Would this bring harm? What are the potential environmental impacts of different adaptation options? These matters would presumably need to be considered in an environmental impact assessment should the road project proceed. Any identified risks would need to be built into a monitoring plan for the project to optimise benefits for the State.

Similarly, the rate of relocation promised by the road project is still unclear. While community enthusiasm for the project is high, relocation depends on access to resources. It is therefore logical that the means and speed of relocation of the community should be monitored as part of the project, should it proceed.

Government presently routinely collects little documentation of the actual effects of over-wash on the government, private sector, or community. This analysis relied heavily on a key 2008 assessment of the effects over-wash. Documentation of disaster events provides the foundation and business case for future remedial action. Government should consider documenting the impact of future events, including noting impacts such as impacts of housing and estimated cost of repairs or other remedial action. These data should be stored for future reference.

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Annex 1. Scenarios Assessed

CASES QUANTIFIED USING A 1:5 YEAR EVENT, 1:40 YEAR EVENT, AND 1:100 YEAR EVENT

1	Entire existing coastal road revetted only: this was not realistic because revetment really requires a functional road of some form, so this was not reported on
2	**ENTIRE COASTAL ROAD REVETMENT accompanied by a new coastal road built to existing specifications** Construction over two years Replaced coastal road lasts for 35 years Coastal population increases so increasing damage
3	**COASTAL ROAD UPGRADE (ELEVATED), accompanied by selected revetment** Construction over two years Upgraded road lasts for 50 years Coastal population increases so increasing damage
4	**INLAND ROAD ESTABLISHED NOW (old road abandoned – this is unrealistic)** Construction over two years Immediate abandonment of the coastal road (so no revetment or its maintenance around the vulnerable Paal, Mosral and Utwe areas) Five years after road completion, two households move every five years
5	**INLAND ROAD (old road maintained for 10 years)** Construction over two years Existing road is not replaced as only maintaining the existing coastal road for 10 years (and yet it could last for up to 20 years with adequate maintenance) Five years after road completion, two households move every five years
6	**INLAND ROAD (old road maintained for 20 years)** Existing road is not replaced as only maintaining the existing coastal road for 20 years, at which point the old road expires Five years after road completion, two households move every five years
7	**INLAND ROAD (old road maintained for 50 years)** Construction over two years Old road re-established to existing specifications after 20 years because of slow migration (displays costs of slow migration) Five years after road completion, two households move every five years
9	**INLAND ROAD CONSTRUCTED IN 10 YEARS' TIME** Commence construction in 2026, complete in 2028 Old road re-established once only after 20 years because of slow migration; maintained thereafter for 20 years Revetment and its maintenance of vulnerable areas around Paal and Mosral and Utwe – allows 20 year maintenance Five years after road completion, two households move every five years
10	**INLAND ROAD CONSTRUCTED IN 20 YEARS' TIME** Commence construction in 2036, complete in 2038 Old road re-established after 20 years because of slow migration; maintained thereafter for 20 years Revetment and its maintenance of vulnerable areas around Paal, Mosral, and Utwe – allows 20 year maintenance Five years after road completion, two households move every five years

SENSITIVITY ANALYSIS

8	**INLAND ROAD (old road maintained for 50 years with no existing road replacement** Construction over two years Old road not re-established to existing specifications after 20 years to display potential cost savings from faster migration Five years after road completion, two households move every five years
11	**Scenario 4 with inland road construction costs 10 per cent higher**
12	**Scenario 4 with faster relocation** Five years after road completion, five households move every five years
13	**Scenario 4 with faster relocation** Two years after road completion one household moves every two years Re-establishment of old road after 20 years because still has slow migration
14	**Scenario 4 with slower relocation** Five years after road completion, one household moves every five years
15	**SHORTENED INLAND ROAD (FROM MALEM TO YESENG ONLY)** One year to buy land; one year construction period Maintenance of old road between Malem and Yeseng as people still need to reach each other Five years after road completion, two households move every five years Re-establishment of old road after 20 years because of slow migration, maintained for 20 years
16	**Scenario 15 with faster migration** One year construction period Two years after road completion, one household moves every two years
17	**Scenario 4 with slower agricultural production take up**

Annex 2. Impacts of Inundation on Communities

Recorded data on the impact of inundation events on families do not appear to exist. In its absence, consultations were conducted with the communities most impacted by inundation on the affected coastline: Malem and Utwe. The purposes in the consultations were to:

- generate some statistics about how over-wash events present affect the community (e.g. cutting them off, affecting their property); and
- get a feel for how the communities might be affected by a new inland road.

To achieve this, community representatives were invited to:

- complete a questionnaire (Annex 3) on the effect of coastal inundation and over-wash; and
- focus group discussions on how the issue should be tackled, with groups providing views and feedback on four key questions (Annex 4), followed by a general discussion.

DATA CLEANING

Responses in some questionnaires were internally inconsistent, with respondents stating that they had never experienced an inundation event but then explaining impacts they had experienced of inundation. These individuals were then recorded as having experienced inundation.

Where respondents described impacts of inundation in terms of weeks and months rather than days, a week was interpreted as seven days and a month as 30 days unless otherwise obvious. Where respondents stated that they relocated because of inundation or spent time cleaning up after an event but did not specify the length of time, a minimum time of 1 day were assigned. Where respondents provided a range of time (e.g. 1–2 weeks), a numeric average was assigned.

RESULTS OF THE QUESTIONNAIRE

70 completed questionnaires were used: 36 from Malem and 34 from Utwe. Two-thirds of respondents identified themselves as heads of household. These were virtually all male. Only two of the 19 women responding identified themselves as heads of households.

TABLE 1. GENERAL INFORMATION ABOUT THE RESPONDENTS

	MALE	FEMALE	HEAD OF HOUSEHOLD?
Malem	67%	33%	64%
Utwe	79%	21%	74%
Total	73%	27%	69%

The households represented by respondents averaged six family members, although the size ranged from one in a household to 10, with seven members being the most common size. Not all questions on the other members of the household were completed, so it was not possible to determine the nature of dependents in each household. From what was provided, a representative household included at least three children under the age of 18.

Not surprisingly for such small communities, many of the families completing the questionnaire were related. Over 80 per cent of all respondents stated that they had always lived in their present village. Just over half stated that they had access to other land in Kosrae.

IMPACTS OF INUNDATION

Of all those responding, 63 per cent advised that they had directly experienced a coastal inundation event or had been affected by one (say, through an impact to services). The proportion of families affected was virtually identical in both villages, with 64 per cent of Malem respondents reporting effects and 62 per cent of Utwe respondents reporting effects.

The most commonly recalled event was that of 2014 which a third of affected respondents named.

Of those affected by inundation, the most commonly reported impact on housing was debris in the yard and resulting damage to crops (breadfruit and fruit trees). Considering that home gardens provide a common source of food in Kosrae, and in view of the likelihood that a representative home includes at least three young dependents, the impact of coastal inundation on food security is likely to be increasingly significant over time. Not surprisingly, the impact of coastal inundation on food security was raised several times in group discussions as being a major concern (see Table 3).

In addition to damage to food supplies, some affected respondents stated that some household possessions were harmed during inundation, with damage to vehicles and furnishings (including television sets) the most commonly reported. Occasionally, items that were damaged in the past by inundation were cited as irreplaceable. These were commonly photographs but also a passport (raised once).

Of those respondents who reported some experience of coastal inundation, the most commonly reported impact on families was clean up, with over ten per cent of all respondents having to spend time to clear yards and or homes of debris. On average, respondents reported spending six days on clean up, with Utwe villagers reporting a longer time spent cleaning on average (seven days in Utwe compared to five in Malem).

The impact of inundation on utilities was notable. On balance, power was the utility most commonly reported affected, with almost a quarter of all respondents stating that power was interrupted as a result of inundation. Power outages resulted in the spoiling of food as freezers thawed, the inability to prepare food, and affected work. A smaller proportion of families lost water, due to broken pipes or power outages (pumping water).

Road breaches affected transport for families, affecting a fifth of all families surveyed. The effect was an inability to get some children to school or employees to work. A reported ten per cent of respondents stated that they had to take time off work following the event, either because they could not access work due to road breaches or because they had to clean up their compounds. This resulted in a loss of earnings to families.

Nine per cent of all respondents stated that their children missed some schooling. This was either again because of road breaches or because uniforms and school items were harmed in the flooding. The average affected child missed two or three days of school. Considering that families usually pay school fees up front, this is a financial cost to families as well as a lost learning opportunity for children.

TABLE 2. INTERRUPTIONS TO UTILITIES FROM INUNDATION EXPERIENCED

	TRANSPORT	WATER	ELECTRICITY	TELEPHONE
Malem	35	9	26	17
Utwe	18	26	29	24
Total	20	16	23	17

The damage to utilities, access or sheer flooding of homes meant that some families relocated temporarily for safety or convenience. Almost one fifth of all respondents surveyed (19 per cent) stated that they had to relocate, with families relocating on average for two days.

HEALTH AND SAFETY

The impact of coastal inundation on health was not extensively reported in the questionnaires. In contrast, this issue was actively discussed in break-out groups. As well as concerns about food security and damage to homes, focus groups stressed the issue of family safety and how this could be harmed by ongoing inundation threats. A key issue here was pollution arising from the inundation of pig pens and septic tanks. On this issue, a couple of respondents had stated in their questionnaires that family members had in the past experienced skin rashes after the floods.

RELCOATION AND OTHER SOLUTIONS

Focus group discussions identified that families in the Malem/ Utwe area felt that—unimpeded—coastal inundation would likely worsen and continuity in the community would be untenable. All representatives suggested that homes would become unsafe, food security harmed, businesses damaged, and ultimately families would not be able to stay in the area. Representatives suggested that families would either have to find a way to move inland or overseas.

Both in questionnaires and in focus groups, community representatives expressed complete support for the establishment of an inland road that would allow families to relocate. They also suggested other options to support ongoing coastal access such as the establishment of wave breakers. Relocation raised several issues:

- Access to land: not all representatives had access to land elsewhere. Only half (52 per cent) of respondents had access to other land outside their existing home, and of those who had land elsewhere, this land was not always in the vicinity of the proposed road. As a result, representatives queried who would access land for them.
- Relocation of the road would enable families to access the interior, but the proposed road project did not include the establishment of new houses for the affected population. Representatives expressed a need for financial assistance to establish new homes in the interior once the road was established. Several groups raised the need for there to be a change to the criteria for government housing loans and or the need for financial assistance to build new homes.

TABLE 3. SUMMARY RESULTS OF FOCUS GROUPS

1 What is your biggest concern/ fear about coastal over-wash and coastal inundation?	

Malem Men's group #1
• Damage to:
  • Food crops
  • Housing
• Inundation of pig pens leading to contamination of area from animal waste and the outbreak of disease
• Safety of human life (dead or alive)
	Malem Men's group #2
	• Damage to properties/ housing
	• Risk of fatalities from storm surge (where people are right near the coastline and waves are strong, or where strong winds bring down trees onto houses)

Malem Women's group #1 • Safety of the family • Damage to properties/ housing/ food crops • Damage to vehicles • Damage to road	**Malem Women's group #2** Damage to: • Housing • Food and root crops Lives of families (safety)

Utwe Men's group #1
• Damage to houses
• Food security
	Utwe Men's group #2
	• Coastal erosion:
	  • Food security
	  • Home safety
	• Health issues
	• Public infrastructure;
	  • School
	  • Utilities and water

Utwe Men's group #3 • Impact on residences • health issues • infrastructure damage • food security	**Utwe Women's group #1** • damage to environment, crops, roads, homes • impact on health
2 What do you think is the answer to over-wash/coastal inundation? What should the government do? What should families and businesses do?	

Malem Men's group #1
• Government needs to:
  • relocate housing
  • improve the access road (main road)
  • immediately maintain power and water system (during a flood)
  • establish a wave breaker
  • set policy direction
• There is a need for housing loans to promote movement inland
• Families need to promote a move inland by sharing access to interior land
• Relocation would be an opportunity for people to get into real estate and for people to lease out properties for business
	Malem Men's group #2
	• We need to relocate families, road and other utilities and infrastructure
	• There is a need for technical assistance to facilitate relocation
	• Government needs to access financial assistance to facilitate relocation
	• We need to adjust the housing loan criteria to enable access to funds
	• On the matter of relocation, we are concerned about the need for families on the coast to have access to land in the interior

Malem Women's group #1
• We need experts to inform relocation etc.
• Government needs to fund:
  • relocation
  • the building of a sea wall
• We need to conserve natural resources to better protect the coast:
  • Sand and gravel
  • Mangrove trees
  • River (canals)
	Malem Women's group #2
	Government needs to:
	  • strengthen/add a seawall
	  • strengthen enforcement of laws governing coastal activities e.g. preventing sand mining
	• Businesses need to help victims of inundation
	• Families and business need to work together to develop inundation preparation plans and bring to local government
	• In the aftermath of an inundation event, businesses need to assist affected families of inundation

Utwe Men's group #1 • Relocate homes, businesses and infrastructure • Climate-proof the road	**Utwe Men's group #2** • Relocate upland • Build a wave breaker • Enforce regulations
Utwe Men's group #3 • Relocate – design and implement programmes for relocation	**Utwe Women's group #1** Relocate. Government should provide funding support (roads, power) Families should support relocation

3 If over-wash and coastal inundation continue but nothing is fixed, what will happen to your family/ business? Would you stay?	

Malem Men's group #1
If nothing changes:
• Families would suffer hunger (because of the impact on crops)
• Properties would be damaged
• The schools would be closed (because of lack of access)
• There would be no access to the public services (e.g. hospitals)
  • Ultimately, people would have to out migrate from Kosrae
• Businesses would be harmed as food and commodities are spoiled.
  • Ultimately, they would go bankrupt
	Malem Men's group #2
	If nothing changes:
	• We would need to out-migrate (abroad)

Malem Women's group #1
• If nothing changes, we would continue to have disruptions to family because of fear, hunger and death
  • We would definitely not be able to stay
  • Housing policies are needed to discourage housing construction near coast
	Malem Women's group #2
	• If nothing changes, family relationships disrupted or despair, which will lead to people to leave the island
	  • We could not stay

Utwe Men's group #1 • Continued damage to housing • No more businesses • A move to higher ground	**Utwe Men's group #2** [discussed in forum]
Utwe Men's group #3 • Life is at risk • We could not stay	**Utwe Women's group #1** • Health issues • Food problems • Businesses affected
4 What do you think of the idea of establishing a new inland road? What would be the biggest change to you and your family/ or business?	
Malem Men's group #1 We support the idea of an interior road. However: • Family ties could be weakened if people are not located close together as before. This would harm social events and functions • Families would face higher fuel expenses as they now live further away from facilities	**Malem Men's group #2** We support the idea of an interior road. We see advantages and disadvantages: • Advantages include that we could increase farming with improved interior access, we would have access to a clean environment and we would be safe • However, moving would be costly and there is a risk that – with freer access to the interior, people from other communities might trash the interior or might steal from others' inland farms
Malem Women's group #1 We fully support the idea of an interior road because we know that we would be safe	**Malem Women's group #2** It is good to go ahead with an inland road because it will lessen their worries
Utwe Men's group #1 • Healthier population • Safety • Cost savings (avoided damage) • Lower transportation costs • Incomes	**Utwe Men's group #2** 100 per cent agree that we should move upland. This would lead to: • Improved health • Better food production • safety
Utwe Men's group #3 [discussed in forum]	**Utwe Women's group #1** • 100 per cent support relocation • Cost – we need financial support

Annex 3.
Kosrae Householder Questionnaire on Coastal Inundation

The questionnaire was broken into three parts. Section targeted information on stakeholder connections to the area and their experiences of coastal inundation. This section also sought information on access to interior land by stakeholders as a means to indicate whether communities would have the opportunity to relocate if they chose.

Section B collected information about how families suffer as a result of coastal inundation. This section collected information on possible impacts in the form of harm to personal effects (possessions, crops etc.), how or if possessions were fixed/replaced, clean up and evacuation impacts, injuries, loss of earnings, and access to services and interruption to utilities and schooling. Section C invited any general comments community representatives wanted to share.

KOSRAE HOUSEHOLDER CONSULTATION ON COASTAL INUNDATION

DATA ENTRY ONLY

Consultation session (village name):

_____

Questionnaire # _____

DATE:

A PERSONAL BACKGROUND

The purpose in this section is to understand your connection to the area and your experiences of coastal inundation.

A1 Your name _____

A2 Your position in the household (circle)

head of household student/ youth Other (please state)

A3 Are you male or female? (circle) Male or Female

A4 Your village (e.g. Utwe, Malem) _____

A5 Including yourself, how many people normally live in your house?

	Age	Male/ female
Person 1		
Person 2		
Person 3		
Person 4		
Person 5		
Person 6		
Person 7		

(Continue on another sheet if necessary)

A6 When did you come to live in this house? (circle/complete)

(i) Always lived here

(ii) Moved here from (town, island) ..... in (year) .....

A7 If you came here to live from elsewhere, why did you move here to begin with?

.....

.....

A8 Please indicate if you or your family own land elsewhere in Kosrae. Please give us a general idea of the location of the area (e.g. coastal area near other village, interior etc.)

.....

.....

A9 Who in your family owns this land? (circle)

Me My parents Other (please indicate)

A10 Have you experienced coastal inundation (coastal floods) in this area in the past? (Circle)

(If NO, go to Section C). Yes No

A11 In what year did you last suffer a coastal inundation event?

.....

B PERSONAL IMPACTS FROM PREVIOUS INUNDATION EVENTS

The purpose in this section is to get an understanding of how families suffer as a result of coastal inundation. To answer these questions, it may help you if you think back to the last time a storm surge hit the area.

PERSONAL EFFECTS

B1 In previous inundation events, did your house get harmed in anyway (flooded, damaged etc.)? If NO, go to question B2. If YES, please state how:

.....

.....

.....

B2 Please indicate any types of item that were destroyed or damaged. E.g. TV, telephone, refrigerator, Furniture, livestock/animals, cash crops that you were producing, subsistence crops, vehicles etc.). If NONE of your items were destroyed or damaged, please go to question B6.

.....

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.....

.....

B3 How did you cover the cost of replacing or fixing the damaged items?

(i) Didn't replace/ fix (ii) Insurance (iii) Private savings
(iv) Extended family (v) Charity donations (vi) Government assistance

(vii) Other (specify)

.....

.....

B4 If you spent money to fix or replace items, roughly how much did you spend? .....

B5 Did you lose any items that are irreplaceable and difficult to value (photos, records, heirlooms etc.)? If YES, which items?

.....

.....

.....

B6 How many days did it take to clean up your house and land after the inundation? ..... days

B7 Did you have to live somewhere else at any point because of the inundation? Yes No

If NO, go to question B11.

B8 If YES, why did you have to stay elsewhere? And for how long did you stay there?

I stayed away because

.....

.....

.....

I stayed away for ..... days

B9 Did staying elsewhere cost you anything? If NO, go to question B11. If YES, what did you have to pay for?

.....

.....

.....

PHYSICAL IMPACTS

B11 Did you or other members of your household suffer any sickness or injury because of the inundation? (circle) Yes No

If NO, go to question B14.

B12 If YES, what kind of the sicknesses/ injuries occurred (e.g. cuts, injuries and infections from slipping in the water, etc.)?

.....

.....

.....

B13 Did you have to pay for medical treatment as a result?(circle) Yes No

EARNINGS

B14 Were any of your household unable to work because of the inundation? Yes No

If NO, go to question B16.

If YES, why were they unable to work? (e.g. road block, staying home to clean up etc.)

.....

.....

.....

B15 Roughly how many days did they miss? ..... days

SERVICES AND UTILITIES

B26 Did you experience disruption in basic services? If YES, what services were disrupted? (Circle all that apply.)

Transport Water supply Electricity Telephone

B21 What problems did these outages cause you?

.....

.....

B22 On average, how long did you have to wait for the services to resume?

.....

.....

.....

B23 Did you have any issues with blocked roads because of the inundation? If YES, what problems arose?

.....

.....

B24 Did any children in the household miss any days of school as a result of the inundation?

If NO, go to Section C.

If YES, why?

.....

.....

B25 How many children missed school? _____ children

B26 How many days did they miss each? _____ days

C FINAL COMMENTS

C1 Would you like to add any comments about the inundation?

.....

.....

.....

.....

.....

.....

.....

.....

This is the end of questionnaire. The results of the survey will be made available to the government around October/November 2015 and these will be released in a report that goes to the government later in the year.

If you would like to find out more about the survey, please contact in the first instance:

Mr Lipar George, Government of Kosrae

THANK YOU FOR HELPING US IN THIS WORK.

Annex 4. Key Questions for Focus Groups

Consider the responses you have individually given in the questionnaire about coastal inundation in Kosrae. In your groups, please discuss and consider the following questions. Please write your answers on the paper provided:

1 What is your biggest concern or fear about coastal over-wash and coastal inundation?

2 What do you think is the answer to over-wash or coastal inundation?
   - What should the government do?
   - What should families and businesses do?

3 If over-wash and coastal inundation continue but nothing is fixed:
   - What will happen to your family/ business?
   - Would you stay?

4 What do you think of the idea of establishing a new inland road? What would be the biggest change to you and your family or business?

Annex 5. Results Tables

BASE CASES								
	Revetment with coastal road	Coastal road upgraded (elevated)	Inland road from 2017				Construction of inland road in 10 years (2026), 2 HH move every 5 years	Construction of inland road in 20 years (2036), 2 HH move every 5 years
			No maintenance of old road	10 years maintenance of old road	20 years maintenance of old road	50 years maintenance of old road		
Total value impacts (discounted @10%)		1044630	728876	721995	719342	717876	1751859	3474953
Total value impacts (discounted @4%)		2091170	323598	313436	306571	297691	4473786	6249642
Total value impacts (undiscounted)		4631956	–1485983	–1499534	–1513085	–1548318	12472606	14305783
Total value benefits (discounted @10%)	–420837	3866497	4182251	4189132	4191785	4193251	3159268	1436174
Total value benefits (discounted @4%)	–1237609	5364262	7131833	7141995	7148860	7157740	2981646	1205790
Total value benefits (undiscounted)	–3462030	9907217	16025156	16023801	16023801	16087491	2066567	233390
Total value costs (discounted @10%)	919822	4165834	6256506	6256506	6256506	7803850	2476360	1855467
Total value costs (discounted @4%)	949418	4299875	6743591	6743591	6743591	9469265	4792047	3824014
Total value costs (undiscounted)	978816	4433016	7164390	7164390	7164390	11975235	7871462	7464550
NPV (discounted @10%)	–1340659	–299337	–2074256	–2067374	–2064721	–3610599	682908	–419294
NPV (discounted @4%)	–2187028	1064387	388242	398404	405270	–2311524	–1810401	–2618224
NPV (undiscounted)	–4440846	5474201	8860766	7529190	7534611	4112256	–5804895	–7231160
BCR (discounted @10%)	–0.46	0.93	0.67	0.67	0.67	0.54	1.28	0.77
BCR (discounted @4%)	–1.30	1.25	1.06	1.06	1.06	0.76	0.62	0.32
BCR (undiscounted)	–3.54	2.23	2.24	2.24	2.24	1.34	0.26	0.03

BASE CASE AND SENSITIVITY ANALYSIS							
	Inland road from 2017 old road abandoned, costs 10% higher	Inland road from 2017 with faster relocation (5 households [HH] move every five years from five years after establishment)	Inland road from 2017 (no maintenance of old road; 1 HH moves every 2 years)	Inland road with slower relocation (no maintenance; 1 HH every 5 years after 5 years from establishment)	Partial inland road from Malem to Yeseng from 2017 (no maintenance of old road; 2 HH move every 5 years)	Partial inland road from Malem to Yeseng from 2017 (no maintenance of old road; 1 HH moves every 2 years)	Inland road from 2017, (no maintenance of old road; 2 HH move every 5 years) – slower agricultural production (4 acres per year)
Total value impacts (discounted @10%)	728876.23	671024.15	226237	725238	3175985	238397	1080810
Total value impacts (discounted @4%)	323598.44	64970.58	–1281213	289202	3287072	–221256	1365483
Total value impacts (undiscounted)	–1485982.84	–2433750.91	–5180973	–1641867	2996165	–1597236	969217
Total value benefits (discounted @10%)	4182251	4240103	4684890	4185888	1735141	1656578	3830317
Total value benefits (discounted @4%)	7131833	7390461	8736645	7166229	4168360	3783100	6089949
Total value benefits (undiscounted)	16025155.78	16972923.85	19720146	16181040	11543008	10132301	13569956
Total value costs (discounted @10%)	6753566	6256506	6256506	6256506	3745994	3745994	6256506
Total value costs (discounted @4%)	7283771	6743591	6743591	6743591	5026751	5026751	6743591
Total value costs (undiscounted)	7737193	7164390	7164390	7164390	7204799	7204799	7164390
NPV (discounted @10%)	–2571316	–2016403	–1571616	–2070618	–2010853	–2089416	–2426189
NPV (discounted @4%)	–151937	646870	1993054	422639	–858391	–1243652	–653642
NPV (undiscounted)	8287963	9808534	12555756	5530604	4338209	2927502	6405566
BCR (discounted @10%)	0.62	0.68	0.75	0.67	0.46	0.44	0.61
BCR (discounted @4%)	0.98	1.10	1.30	1.06	0.83	0.75	0.90
BCR (undiscounted)	2.07	2.37	2.75	2.26	1.60	1.41	1.89

The **Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR)** is a regional program which aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes (i.e. 'climate change and disaster risk mainstreaming').

The PPCR-PR is implemented by the Secretariat of the Pacific Regional Environment Program (SPREP) and Asian Development Bank (ADB) and is funded through the Climate Investment Funds (CIF).

SPREP
Secretariat of the Pacific Regional Environment Programme