The Kosrae Shoreline Management Plan

Summary of Recommendations




May 2000

Development Review Commission

Contents

1 INTRODUCTION

The Kosrae Shoreline Management Plan aims to provide a framework for coastal defense policies and to set objectives for future development and resource management, over the next 20 or so years, within the context of coastal erosion and coastal hazard management.

The main objectives of the completed plan are to:

- Assess a range of strategic coastal management options, in terms of limiting the future impacts of coastal erosion, flooding and storm damage on the people and developed infrastructure, for the entire coastline of Kosrae.

- Inform the Government and people of Kosrae of potential future coastal erosion and coastal hazard risks to aid planning for future development.

- Identify opportunities for maintaining and enhancing the natural coastal environment for the benefit of the people of Kosrae.

- Establish necessary monitoring and data collection to enable a better understanding of the effects of natural coastal processes on the coastline of Kosrae, and to help understand the potential impacts of future risks such as those posed by climate change.

This report is a summary of the main recommendations and conclusions that have been developed and begun to be implemented over the last eighteen months. The full technical report, which discusses the natural physical environment and coastal processes that shape the coastline of Kosrae, the human and built environment that is acted upon by these process and which can also impact and influence the natural coastal evolution, and the assessment of strategic management options for each length of coastline around Kosrae and upon which these recommendations have been based, is available from the DRC Office.

It is vital to stress that coastal hazards, such as erosion, flooding and storm damage, will be a major issue for Kosrae for many years to come. There is no quick and easy solution to these problems. The difficult part is still ahead of the Government and people of Kosrae, to gradual reduce the levels of risk posed by coastal hazards on their lives, property and infrastructure through:

- **careful management of human activities that impact on the coastal zone**
- **the future development, and gradual movement, of property and infrastructure away from coastal hazard risk areas.**

The benefits of such an approach will not be immediately obvious – the risks posed by coastal hazards can only be gradually reduced through time and the benefits often only realized after a severe storm or other extreme coastal hazard has occurred.

2 COASTAL HAZARDS ON KOSRAE

2.1 Coastal Erosion on Kosrae

Coastal erosion is the loss of land due to a landward movement of the beach or shoreline. Over the latter half of the last century natural coastal processes have caused a general landward retreat of the beach around most of Kosrae. Over this period, the rate of this retreat has been exacerbated by human activities.

Possibly the most significant factor contributing to the changes being experienced around the coastline of Kosrae over the last 100 years has been the pattern of typhoon and major storm activity. Typhoon events during the 1800's and three events between 1890 and 1905, whilst causing much damage to the island, also resulted in the evolution of the coastline over the early part of the last century by:

- depositing large volumes of sand and coral from the shallower areas of the coral reef onto the reef flat which in turn supplied sand and coral to the beaches allowing them to maintain their position or build out.
- developing large banks of coral rubble on the outer reef and shingle ridges on the reef flat which provided greater protection to these beaches from waves, and provided a suitable habitat for shoreline mangroves and seagrass areas to develop on the inner reef flat on sections of the coastline where they would normally not be found (e.g. the Malem coast).

Since 1905, there has been no typhoons to directly affect Kosrae and few significant storms. The effect of this has:

- resulted in an insufficient supply of beach sands and cobbles to maintain the seaward position of shoreline that had developed, resulting in a general naturally occurring, landward retreat over the last 50 or so years to a more stable position.
- reduced the level of protection, from the effects of waves, to the beaches and shoreline provided by the coral rubble banks on the outer parts of the reef as these rubble banks are gradually broken down.

Figure 1
The Finaunpes and Pukusruk coastline in 1944.

Note the large banks of coral rubble over the reef flat around Foko Finaunpes and down along the Pukusruk coastline which provided much protection to this coastline. Similar banks of coral rubble occurred along the Malem coastline. It is the removal of these banks due to natural breakdown of the coral rubble and removal for development projects that has been the cause of much of the coastal erosion around Kosrae.

However, it is not only the pattern of extreme coastal events that has influenced the evolution of the coastline over the last century. The coastline is never static but constantly changing in response to the natural daily, monthly and seasonal variations in coastal processes such as winds, waves and water levels.

Over the last 40 or so years on Kosrae, human impacts have significantly exacerbated coastal erosion. These effects are directly linked to the rapidly increasing population, development needs and changes in construction practices. The most detrimental practices have included:

- Removal of coral rubble from the reef
- Removal of sand and cobbles from the beach
- Dredging of the reef flat at Tafunsak.
- Altering the position of river outlets or changing swamp drainage patterns and flows.
- Building inappropriate coast defenses and land reclamation.

The most significant of these impacts has been the removal of coral rubble from the outer reef flat for sub-base for the road, construction of the causeway and other development projects. Although much of this removal was conducted between ten to forty years ago, these effects are still causing changes at the coastline.

Figure 2
Dredging of the reef at Tafunsak.

The dredging in front of Tafunsak village during construction of the airport caused rapid erosion of the shoreline. This was because the dredged pits affected both the natural movements of sand between the beach and the reef flat,the movement of sand along the reef flat, by trapping sand in the pits.

Despite considerable opinion concerning the construction of the airport, this construction has **not** been responsible for the erosion evident around Kosrae other than the severe erosion that occurred in the immediate vicinity of Tafunsak village associated with the dredge pits. Furthermore, the closure of the Insrefusr Channel has not been a dominant cause of the erosion at Finaunpes. Re-opening the channel will not stop the erosion problems along the Sandy Beach coastline.

In summary, the entire coastline of Kosrae has experienced a period of rapid change primarily caused by an insufficient supply of sediments to the beaches and a reduction in the protection from waves provided by coral rubble deposits on the outer reef flat. The resulting coastal erosion can be attributed to natural factors. However, human actions have significantly exacerbated the rate of erosion.

2.2 Future coastal erosion

Over the last century the coastline around Kosrae has retreated back to a position where, on average, it has likely been for the last 3000 years or so. In general, future erosion on Kosrae may well be increasingly dominated by episodic events (e.g. storms) rather than a continual ongoing process. However, this will depend on:

- The frequency and magnitude of storm conditions.
- The future impacts of climate change (particularly changes in the frequency and magnitude of storm conditions and long term wind and wave conditions).
- The impacts the people of Kosrae have on the coastline.

Despite this, there are a number of critical locations around Kosrae where the potential for coastal erosion is likely to be most severe. These include:

- The Sialat, Finfukul and Yekula section of coastline (probably the most critical section on Kosrae).
- Sandy Beach coastline
- The South Finfokoa / North Pukusruk section in Lelu
- The coastline north of the Malem River outlet.
- The Walung coastline between Insiaf and Pilyuul (old Elementary School)
- The outer coastline between Utwe and Walung (Walunga)

Figure 3
The Finfukal coastline.

The coastline between Sialat and Yekula is likely to be one of the most problematic areas in the future, in terms of protecting the infrastructure located on the immediate hinterland.

The areas listed above are likely to experience the most significant rate of coastal erosion over the coming years. However, there are many other areas where coastal erosion, although occurring at a lesser rate, may be of greater concern due to the proximity of infrastructure or housing to the coastline, particularly:

- Kotfwa, Fukrin & Pal areas of Malem
- Finfoko, Tafunsak
- Inpuspusa in Utwe (from the Municipal boundary to Skarac and Sacracr)
- Mosral

Furthermore, the Yeseng, Mosral and Kuplu sections of coastline have the potential to be extremely dynamic (i.e. large changes in the position of the coastline could occur in the future).

2.3 Future extreme coastal events

Of greater concern than future coastal erosion is the potential effects of a future severe storm, typhoon or tsunami on the coastline of Kosrae. Approximately seven typhoons have passed within 200km of Kosrae since 1890 and a number of small tsunamis have also occurred. **An extreme natural event, such as a typhoon or tsunami can be expected to directly affect Kosrae in the future.** Areas at risk from storm damage and flooding are shown on Figure 4.

Year	Typhoon or Tsunami event
1835	Typhoon occurred
1891	Typhoon destroyed all but six houses and virtually all breadfruit and coconut trees destroyed
1900	Typhoon occurred
1905	Typhoon lasted seven hours with much destruction of property and trees
1979	Small Tsunami affected Kosrae
1986	Typhoon "Lola" resulted in strong winds affecting Kosrae
1992	Typhoon "Axel" passed 60 miles to the north of Kosrae

Table 1
Summary of typhoons and tsunamis that have affected Kosrae over the last 200 years.

Virtually everyone on Kosrae lives on land that is less than 4m (12 feet) above mean sea level. All of this land is at risk from the impacts of a typhoon or tsunami with there being potential for significant loss of life and destruction of a high percentage of residential property from the effects of wind, high tides and waves. The five main villages on Kosrae are all at significant risk

All of Kosrae's infrastructure (roads, utilities) are located on low land close to the coastline. There will be significant damage to the road and loss of power and telecommunication infrastructure if a typhoon were to directly affect Kosrae. **None of the existing coastal defenses around the island will protect the coastline, or the land behind, from the effects of high water levels and waves caused by a typhoon or tsunami.**

A typhoon or severe storm would also destroy much of the mature mangrove areas such as those at Okat and Yela and have a short term impact (10 to 20 years) on the coral reef. However, typhoon events are a vital process in limiting long term coastal erosion by re-supplying sand, cobbles and coral rubble to the reef flat and coastline from the coral reef.

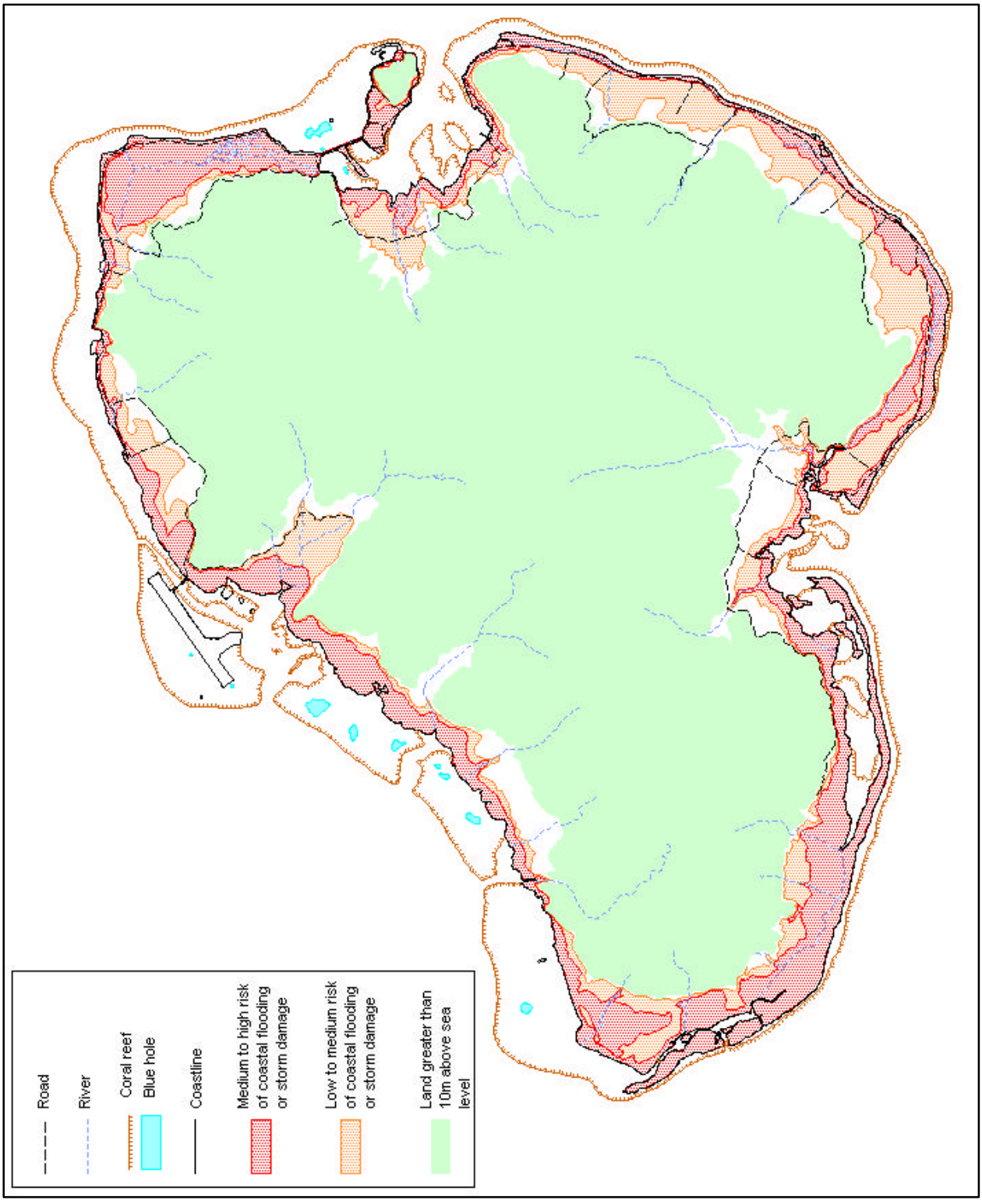

Figure 4 Areas of high to medium and medium to low risk of coastal flooding and storm damage on Kosrae

2.4 Sea level rise, climate change and climate variability

Mean sea level rise is one of the most well documented consequences of climate change caused by human induced global warming. Mean sea levels over the last 100 years have risen 4 to 8 inches in the Pacific. It is estimated that mean sea levels over the next 100 years will rise by between 6 inches and 38 inches, with a current best guess of 20 inches. There is also speculation that typhoon events and severe storms could also become more frequent or severe as ocean temperatures increase.

Figure 5
Storm waves at Malem

Climate change means changes that occur over a decade or longer. **Climate variability** refers to seasonal or inter-annual (year to year) changes. The location of much infrastructure and residential property on Kosrae is presently at extremely high risk **existing climate variability**, such as changes caused by El Nino / La Nina periods, storms, high water levels, typhoons and tsunamis. For example:

When El Nino is occurring:	There is a greater risk of typhoons affecting Kosrae. Water levels tend to generally lower.
When El Nino is not occurring:	There is a lower risk of typhoon conditions Water levels can be as much as 20 inches higher than occur during periods of El Nino (due to stronger tradewinds).

It is the risks posed by these existing threats, coupled by the pressure of increasing coastal development, increasing population and increase coastal resource usage that are the greatest coastal management problems on Kosrae (and most Pacific Islands) today.

The consequences of climate change, such as sea level rise and changes in weather patterns will not cause new problems and risks on Kosrae. It will simply gradually increase or exacerbate the frequency and magnitude of the risks and problems caused by existing coastal hazards.

Reducing the present risks to the people and infrastructure of Kosrae posed by existing natural climate variability will be the most effective way in reducing the coastal hazard risks posed by future climate changes.

3 FUTURE COASTAL MANAGEMENT

3.1 Introduction

Adaption to the risks posed by current and future coastal hazards on Kosrae falls under three fundamental coastal management activities:

1. Increase understanding of how the natural coastline evolves due to the natural processes acting upon it through continued data gathering (e.g. beach profiling, tide gauge recording at Lelu Harbor) and management and decision technologies (e.g. GIS).
2. Continued public education to minimize human impacts on the natural coastal defenses and to increase awareness of the physical and biological interactions that occur within the entire coastal zone.
3. Implementation of the three main coastal adaption options:

    - Managed retreat – moving essential infrastructure, property etc away from coastal hazard areas and allowing the natural coastal defenses to protect Kosrae's built environment.
    - Accomodation – living with the risk of coastal hazards
    - Protection – providing structures to attempt to protect the coastal hinterland or to try to manage the dynamic nature of the shoreline.

All three of these activities are being actively implemented on Kosrae **and will need to be continued for as long as people on Kosrae live close to the coastline.** The following sections outline the principal coastal adaption and management recommendations for the next ten to twenty years on Kosrae.

3.2 The Natural Environment

The coastal ecosystem on Kosrae is the most effective coastal defense that protects the island from the effects of coastal hazards. This ecosystems include the watersheds, wetlands and swamp forests, mangroves, beaches, reef flat, the coral reef and immediate marine environment. Although systems, such as beaches, are often perceived to be a separate habitat, in reality they are a small part of this much larger coastal ecosystem. The effectiveness of the natural coastal protection provided by this coastal ecosystem is dependent upon the health of, and the natural interactions between, each of these systems.

The careful management of the natural coastal environment and the resources found there, is the single most important coastal defense policy for Kosrae.

The following sections outline the principal coastal management recommendations for managing the natural coastline of Kosrae with respect to coastal erosion and coastal hazard management.

3.2.1 The coral reef and the reef flat

The coral reef and reef flat is the single most important natural feature protecting the land on Kosrae from erosion and storm damage. It provides:

- direct protection from waves
- the major source of sediment, produced by reef biota, that feeds Kosrae's beaches.
- the controlling environment for the natural development and evolution of the beaches and shoreline mangrove areas.

Kosrae's living coral reef is in a relatively healthy state in terms of the protection it provides to the shoreline. However, the reef flat has previously experienced significant damage due to human activities, principally the removal of coral rubble for development. Although this practice no longer occurs except on a very small scale, the impact from such activities previously, has been the major cause in the long term erosion of the shoreline of Kosrae.

The key threats to the protection provided by the coral reef and reef flat are primarily:

- Detrimental fishing practices (chlorox, poison leaf)
- Land based pollution:- pollutants from the Okat Harbor area, an increasing number of septic tanks and pig pens located close to the coastline or other water areas, and the dumping of wastes such as oil and batteries.
- Changes in the volume of river flows due to upland land practices or altering rivers or drainage channels.
- Increasing sediment washed from land due to upland land clearing, land filling, agricultural or other practices
- Re-commencement of the removal of coral rubble, shingle and sand from the reef flat.

Similar activities are also a threat to the seagrass beds which are vital in trapping sand on the reef flat and helping to reduce waves before they reach the shoreline.

Figure 6
Dumped paint cans at Semo

Waste management and pollution is increasingly becoming a threat to the health of Kosrae's natural environment, particularly that of the coral reef.

Recommendations

1. It is **recommended** that every effort needs to be directed at continuing to protect the health of Kosrae's living coral reef from land based human impacts.

2. It is **recommended** that the present practice of **not** removing coral rubble, shingle and sand from the reef flat be continued.

3. It is **recommended** that a full Environmental Impact Assessment is carried out by qualified personnel before any further reef flat dredging is permitted. However, it is strongly **recommended** that no further dredging of any part of the fringing reef flat be conducted.

4. It is **recommended** that stricter regulation, enforcement, training and education aimed at managing and reducing both residential and industrial sources of pollution will be vital for the long-term health of Kosrae's living reef biota.

3.2.2 Beaches and the shoreline

The beach on Kosrae is a buffer zone between the land and the sea. Beaches on Kosrae can change on a daily, monthly and seasonal basis mainly in response to changing wave conditions.

Beaches do not stay in one place. This leads to one of the most common problems around the world – development close to the coastline requires the beach to be in a fixed location when the natural tendency is for it to change.

Beach changes can take place without causing the coastline to erode. Storm conditions, or when larger waves occur at the same time as a high tide, may cause what appears to be erosion as the beach shape re-adjusts to the large waves (see Figure). This does not necessarily mean that the coastline is eroding as the beach may slowly build back up after the storm. However, coastal erosion occurs when the beach does not build back up resulting in a long term loss of land as the entire beach moves landward.

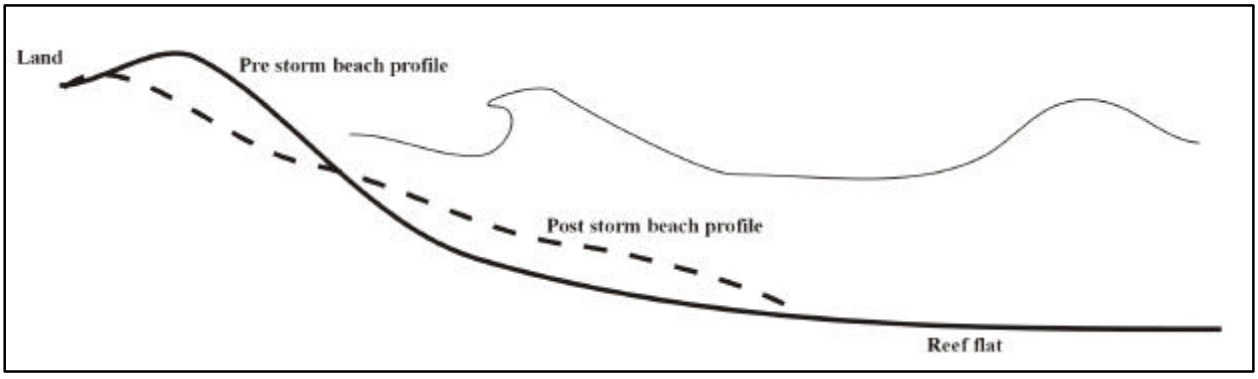

Figure 7 Beach profile changes caused by storms or large waves

An important aspect of the natural behavior of a beach is the movement of beach sediments, particularly on a sand beach. Beach sediments are moved both along the beach, (called longshore drift) and across the beach onto the reef flat and back (onshore-offshore movement) . These movements are controlled primarily by waves and currents. If more beach sediment is transported from an area of beach, than is transported to the same area, then coastal erosion will occur. Activities that disrupt or change this natural movement of beach sediments, such as building sea walls, normally leads to increased coastal erosion problems or loss of beach.

Figure 8
Sand mining on Kosrae

The amount of sand mining occurring around the coastline of Kosrae is expected to increase over the next few years. Sand mining directly increases the rate of coastal erosion experienced on an eroding coastline as it removes even more sand from the beach. However, until alternative sand sources, such crushed volcanic rock, are developed on the island to meet current development demands it will be very difficult to reduce the impacts from such activities.

Key threats to the beach and the shoreline areas of Kosrae, which will limit their effectiveness as a part of the natural coastal defenses and lead to further long term coastal erosion include:

- Increased sand and cobble mining from the beach and immediate hinterland as population and the rate of development continue to increase and the availability of land based and other current sand sources decreases.
- Further infrastructure of property development in the immediate beach hinterland
- Clearing of coastal strand vegetation
- Construction of piecemeal coastal defense structures or land reclamation over the beach region.

Recommendations

1. It is **recommended** that a long-term source of construction sand needs to be developed to meet Kosrae's future development needs. Existing sand resources in the coastal hinterland are extremely limited and increasingly will not meet Kosrae's construction demands.

2. It is **recommended** that sand mining from the beaches of Kosrae needs to be regulated. However, experience from other small island developing states suggests that this is likely to only be effective once a suitable long-term alternative to beach sand is available.

3. It is **recommended** that vegetation clearing be discouraged for at least 50m behind the vegetation line at the shoreline. Where possible the planting of typical coastal strand vegetation should be encouraged.

4. It is **recommended** that the construction of new coastal defenses and land reclamation over the beach be strictly controlled and regulated through the Development Review Process. This is particularly important on the exposed sections of coastline (i.e. those facing the open ocean).

3.2.3 Mangroves

Mangrove areas on Kosrae provide direct coastal protection for about 22% of the coastline, Table 2. Mangroves are also an important component of the overall natural coastal defenses (but do not provide direct coastal protection) between Utwe and Walung, Kuplu and Mutunnenea.

Mangroves only provide coastal protection along relatively sheltered coastlines, i.e. those that experience low wave energy. The mangroves along the coastline between Tafunsak and Mwot is the only significant strand that provides protection in an exposed (reef flat) location. All others areas have developed in more sheltered estuarial locations or behind storm beach deposits.

Location	Approximate length of coastline Km (miles)
Lelu Harbor	4.5 (2.8)
Malsu, Tafunsak	0.1 (0.06)
Kemuen, Tafunsak to Mwot	10.0 (6.2)
Utwe Harbor	3.1 (1.9)
Tenwak	0.4 (0.25)
TOTAL	**18.1(11.2)**

Table 2
Locations where mangroves provide direct coastal protection to the coastline

The narrow strands of mangroves that previously occurred on the outer coastlines, such as along the Malem coastline, provided little effective coastal protection from wave and storm conditions. Mangroves only developed along coastlines such as Malem, due to the protection from waves provided by the coral rubble banks that were previously located on the outer part of the reef flat. The loss of mangroves from these more exposed coastlines is related to the loss of the rubble banks and has not been a dominant cause of the erosion along these sections of coastline.

Present rates of mangrove removal by humans along the sections of coastline where mangroves do provide effective coastline protection has not yet resulted in coastal erosion but may have the potential to do so in the future.

Key threats to the level of protection to the coastline provided by the above areas of mangrove come dominantly from:

- Harvesting of seaward fringe mangroves or over harvesting in localized areas
- Further land filling or road construction through mangrove areas.
- Altering river flows or increasing sedimentation due to poor land management practices.
- Typhoon or storm damage which has the potential to destroy large areas of mature mangrove strands
- Accelerated sea level rise caused by global warming

Recommendations

Developing sustainable mangrove harvesting practices and mangrove replanting are major components of current US Forestry Service assistance to Kosrae. Mangrove replanting for coastal protection purposes is only a feasible option in a few other areas (out-with those identified above).

1. It is **recommended** that mangrove replanting, to provide natural coastal protection to the coastline, is a suitable mechanism in the following areas:

    - Lelu lagoon:- potentially from Mitais, all along the northern coastline of Lelu Island, the Causeway and Finpukal
    - Lelu Harbor:- Mutunnenea area (south of the bridge)
    - Tafuyat:- mainly the area where mangroves died off due to the oil spill that occurred sometime in the 1980's.

2. It is **recommended** that the area of mangrove replanting should be at least 50 meters wide. This is approximately the width, in a mature mangrove strand, that would effectively dissipate a 1m high wave.

3. Should a severe storm or typhoon affect the mangrove strands on Kosrae, it is **recommended** that human activity, such as the removal of felled trees, be discouraged from the damaged areas and immediate surroundings to allow the damaged area to recover naturally.

4. It is **recommended**, from a coastal protection viewpoint, that harvesting of mangrove timber is discouraged from within 100m of the outer mangrove fringe and from within 50m of major channels.

3.2.4 Wetland areas and rivers

Both fresh and salt water wetland areas have an indirect but vital role to play in protecting the coastline from long term coastal erosion. In essence the wetland areas protect the coral reef by:

- helping control the flow of water from land to the reef during periods of heavy rain.
- helping trap fine sediments washed down that would impact on the living coral reef and reef flat sea grasses if allowed to wash out onto the reef.

Wetland areas function by transporting water at a very slow rate over a large area of wetland. When roads and other filling cross the wetland areas and block this flow of water, or where the flow is restricted to a few culverts, this vastly reduces the effectiveness of the wetlands to transport water from inland to the reef. Development of the circumferential road had a major impact on the effectiveness of the wetland areas in Malem Municipality directly resulting in many of the river outlets blocking up. The construction of farm roads across the wetland swamp areas has also had a significant impact and is a cause of some of the flooding problems, particularly in the Pukensukar area.

Figure 9
The man-made drainage channel between Leap and Pilyuul in Walung.

In the early 1970's a drainage channel, a few feet wide, was cut through the beach at Leap in Walung. Over the following 30 years, tidal currents increased the width of the channel to well over 100 feet. This caused much loss of land on either side of the channel and resulted in worse flooding of the land that was initially intended to be drained. Attempts to control the channel by building sea walls have not been successful.

Key threats to the function and effectiveness of the wetland areas on Kosrae in the future will come from dominantly human activities including:

- Draining of wetland areas
- changing drainage patterns through the wetlands (e.g. constructing new drainage channels)
- the construction of farm roads through the wetland areas
- land filling large areas of wetland
- developing or altering river outlets

Recommendations

1. Where it is deemed necessary to develop swamp areas for activities such as agriculture, it is **recommended** that buffer zones of at least 100m be established around rivers and major drainage channels and along the coastal edge of the swamp.

2. It is **recommended** that that further farm roads through wetland swamp areas, particularly between Tenwak and Kuplu, be discouraged.

3. It is **recommended** that all future culverts and bridges over natural drainage channels and rivers are of sufficient size to have as little influence as possible on the passage of flood flows due to high rainfall events.

4. The development or alteration of artificial river or drainage channels outlets is **not recommended** and should be controlled within the Development Review Permitting Process.

3.3 The Built Environment

3.3.1 Introduction

Coastal erosion and risks posed by coastal hazard are only a problem to property and infrastructure that is located too close to the coastline. Over the last fifty or so years, the risk of damage to property and infrastructure from coastal hazards has increased rapidly, primarily due to:

- A rapidly increasing population
- An increasing rate of development situated close to the coastline
- Increasing concentration of development in the main villages on Kosrae.

The following section outlines some of the key land management and development recommendations that will be necessary if the risk of damage from coastal erosion and coastal hazards to property and infrastructure is to be reduced.

3.3.2 Infrastructure

Virtually all of Kosrae's infrastructure, (roads, power and telecommunication lines) between Tafunsak and Utwe villages (with the exception of the stretch between Mutunnenea and Tafuyat), can be considered at high risk from damage due to coastal erosion, flooding or storm damage. Table 3 summarizes the most critical locations where infrastructure is threatened.

Location	Approximate critical length at risk km (miles)
Sialat – Tafunsak	2.4 (1.5)
Finaunpes	0.5 (0.3)
Pukusruk – Finpukal	2.5 (1.5)
Causeway/North Lelu	1.7 (1.1)
South Lelu	0.6 (0.4)
Tafeyut	0.5 (0.3)
Leyot	1.5 (1.0)
Piluul/Malem/Yeseng	3.9 (2.4)
Mosral	1.6 (1.0)
Inpuspusa & Utwe	1.9 (1.2)
TOTAL	**17.1km (10.7miles)**

Table 3
Areas of infrastructure at risk from coastal hazards

Of these areas, the following sections of the road are most at risk:

- between Sialat and Yekula in Tafunsak
- the Leyot area in Lelu
- the Kotfwa to Puk; and Mosral areas in Malem,
- the Inpuspusa area in Utwe.

Figure 10
Storm damage to the road at Kotfwa in Malem

Recommendations

1. Building further sea walls or other forms of coastal defenses **is not a recommended, appropriate or affordable option** for the long-term protection of **most** of the existing infrastructure at risk from coastal hazards.

2. With the current re-negotiation of the Compact Funding, it is **recommended** that now is an ideal opportunity for the Government of Kosrae to consider a program of developing Kosrae's essential infrastructure inland away from such high risk areas. Within the next 10 to 15 years an inland road will be required between Utwe and Tenwak, and between Mutunnenea and Yekula or Wiya. Over this time, it is **recommended** that this road be developed as the main road linking the Municipalities.

   Approximately 12km (7.6 miles) of inland road has already been developed and will require upgrading and widening. Approximately a further 7 km (4.5 miles) of new road will need to be constructed. Table 2 summarizes the requirements.

Location	Approximate length of road km (miles)	Upgrade or new road
Sialat – Mutunnenea	4.4 (2.8)	Upgrade existing inland road
Pilyuul – Malem	3.4 (2.2)	Upgrade existing inland road
Mosral	1.6 (1.0)	Upgrade existing inland road
Finsrom – Utwe	2.5 (1.6)	Upgrade existing inland road
TOTAL	**11.9km (7.6miles)**	
Sialat – Wiya	1.5 (0.9)	Develop new road inland
Tenwak – Pilyuul	1.6 (1.0)	Develop new road inland
Malem – Utwe (Finsrom)	4.0 (2.5)	Develop new road inland
TOTAL	**7.1km (4.4miles)**	

Table 4 Approximate lengths of inland road to be upgraded or constructed

3. It is **recommended** that the existing practice of constructing the inland road around the perimeter of the lower slopes of the volcanic part of the island, above the freshwater swamp areas be continued, taking due care to minimize road slopes, run-off, and ensuring adequate culverts are installed to minimize changes to drainage patterns and to cope with periods of heavy rainfall.

4. It is **recommended** that in developing the new sections of inland road, priority be given to:

    - Extend the inland road between Malem village (Mutacsrisr) and Mosral
    - developing the road behind Sialat and Finfukul to Yekula or Wiya

5. It is **recommended** that any further development of the circumferential road beyond Okat bridge, towards Walung, be constructed around the perimeter of the lower slopes of the volcanic part of the island above freshwater swamp areas, taking due care to minimize road slopes, run-off, and ensuring adequate culverts are installed to minimize changes to drainage patterns and to cope with periods of heavy rainfall.

6. Upgrading and construction of coastal defenses is **recommended** to protect the existing road at certain key areas where there is little opportunity to develop further inland. These areas are summarized in Section 3.5.1

3.3.3 Residential Property

Most residential and other private property on Kosrae is at risk from the effects of coastal hazards. The problem is almost entirely due to housing being:

- built on land that is too low lying
- built in mangrove or swamp areas
- built on land too close to the coastline

Figure 11
Buildings located this close to the coastline are at risk from virtually every potential coastal hazard

Recommendations

1. It is **recommended** that, over the next ten to fifteen years, reducing the number of residential properties constructed or located within coastal hazard areas is of the highest priority.

2. It is **recommended** that the Government assist individuals in developing residential property out-with coastal hazard risk areas by gradually developing the existing essential infrastructure (roads, electricity, telecommunications) along an inland route as recommended above.

3. It is **recommended** that where new development and property construction does occur close to the coastline, a general set-back zone of at least 100 feet from the vegetation line at the coastline be adopted (see Figure).

4. Setback limits are more difficult to develop for areas with higher population densities, such as the main villages on Kosrae. For the main villages in Kosrae, the following is strongly recommended:

Village	Recommendations
Walung Insiaf, Finenon Leap, Pilyuul	• Recommended that no further development or property construction is conducted between Insiaf and Pilyuul (old Elementary school). • Where possible encourage the gradual relocation of existing properties in these areas to locations of lower coastal hazard risks
Tafunsak Finfoko, Sialat, Saolung	• Recommended that no further development or new property construction is conducted to the seaward side of the road through Tafunsak village • Where possible encourage the gradual relocation of existing properties in these areas to locations of lower coastal hazard risks
Lelu Lelu Island	• Recommended that no further reclamation of land is conducted on Lelu Island • Recommended that no further development or new property construction is conducted to the seaward side of any part of the perimeter paved road around Lelu Island
Lelu Sansrik	• Recommended that no further reclamation of land over the beach is conducted in any part of the village. • Recommended that no further development or new property construction is conducted to the seaward side of the circumferential road in Sansrik
Malem Village Yewak, Masis, Inpea, Mutenpal Fukrin	• Recommended that no further development or new property construction occurs between the circumferential road and the coastline. • Where possible encourage the gradual relocation of existing properties located seaward of the circumferential road in these areas to locations of lower coastal hazard risks
Malem Village Kotfwa, Pal	• Recommended that no further development or new property construction occurs, both on the seaward side of the circumferential road, and on the immediate landward side. • Where possible encourage the gradual relocation of existing properties in these areas to locations of lower coastal hazard risks

Table 5 Recommendations for reducing future coastal hazard risks in the main villages on Kosrae

Village	Recommendations
Utwe Village Inpuspusa, Skanac, Sacracr	• Recommended that no further development or new property construction occurs on the seaward side of the circumferential road particularly at Skanac and Sacracr • Where possible encourage the gradual relocation of existing properties in these locations to areas of lower coastal hazard risks
Utwe Village Inposral, Finyalu, Inya	• Recommended that no further reclamation of land is conducted, seaward of the present sea wall between the Marina and the Elementary School / bridge

Table 5 cont. Recommendations for reducing future coastal hazard risks in the main villages on Kosrae

5. It is **recommended** that the construction of sea walls or other forms of coastal defense to protect individual property is not permitted where there is no existing coastal protection structures. Future construction of sea walls or other forms of low cost coastal defenses **is not a recommended option** for the protection of residential property out-with the locations defined in Section 3.3.5.

6. It is **recommended** that land owners / housebuilders are advised that no hard structures will be permitted in front of newly built properties that have been located seaward of the circumferential road.

7. It is **recommended** that the DRC continue to work with the Housing Renovation Loan Fund Office (Department of Commerce and Industry) and the Rural Development Office (USDA) to minimize the development of loan-funded housing within coastal hazard areas.

8. If it is felt that regulation of residential development is required in coastal hazard areas, above the measures that have been incorporated within the Housing Renovation Loan Fund and Rural Development processes, it is **recommended** that changes be made to the Development Review Process to include all residential housing.

3.3.4 Private sector

Other than harbors or ports, there are very few types of business or commercial development that **need** to be located close to the coastline or in coastal hazard risk areas.

Key issues for future commercial development with respect to coastal erosion and hazard management are likely to be:

- Development on eroding coastlines or in coastal hazard risk areas (particularly tourism related)
- Decline in water quality due to pollutant or sewage discharge
- Unsustainable usage of natural coastal resources for commercial purposes
- Environmental degradation through poor site planning and construction practices

Figure 12
Tourism development located in high risk coastal hazard areas is a common problem

Recommendations

1. Future tourism, and other major commercial development is controlled within the Development Review Process. It is **recommended** that the use of Environmental Impact Assessments be continued as a pre-requisite for all major development projects.

2. Through the Development Review Process, it is **recommended** that no commercial development be permitted in high risk coastal hazard areas (and certainly not within 100 feet of the coastline or on land that could potentially flood).

3. The risk to develop land with any coastal hazard risk for commercial purposes, must be borne by the Developer. It is **recommended** that, at the project review stage, it is made clear to the Developer that the construction of coastal defenses **will not** be permitted during the lifetime of the development to protect the development from storm damage or flooding where no coastal defenses currently exist.

4. It is **recommended** that the Development Review Process ensures that appropriate technology be utilized to ensure that effluent discharge to the fresh water or marine environment from any proposed commercial development has minimal detrimental or cumulative impact.

3.3.5 The Need for Coastal Defenses

A common response to the threats of coastal erosion and coastal hazards is to build sea walls or other form of coastal defenses. On Kosrae this approach has failed to resolve many of the erosion problems and in a number of places made the problem worse. Economic constraints have resulted in many inadequate sea walls (such as around Lelu island) which provide a very low standard of protection to the land behind against coastal hazards. More effective but more expensive coastal protection is not economically justifiable other than at a small number of locations around the island (effective coastal defenses generally cost between $500 and $1,500 per linear foot, for example the Tafunsak sea wall cost $1,300 per foot of coastline).

Figure 13
Damaged sea wall on Lelu Island

Most of the sea walls around Lelu Island require frequent maintenance and would not be sufficient to protect the land during periods of large waves

Building sea walls and other coastal defenses does not stop coastal erosion, only nature can do that. Coastal defenses can only reduce the risk of loss of land immediately behind the defenses in the short term (10's of years). No coastal defense on Kosrae will protect the land behind it from the effects of an extreme event such as a typhoon or significant tsunami**. Even with coastal defenses, people or infrastructure will still be at considerable risk from storm damage and flooding on Kosrae.**

Figure 14
The rock revetment at Finaunpes
Two or three different types of sea walls have been built at places like Finaunpes and Malem over the last 30 years. Each time the sea wall has failed to protect the land. Each time the walls have been rebuilt they have become larger, longer and have cost much more to construct. Building sea walls enters the government of Kosrae into future financial commitments to continue to protect areas where sea walls have been built, through maintaining and upgrading these walls. Already this is a considerable financial burden on the State and Municipal Governments.

Both the State and Municipal Governments on Kosrae have a considerable future financial commitment in ensuring existing coastal defenses are maintained and upgraded to provide a satisfactory level of protection before further coastal defenses can be planned.

Recommendations

1. It is **recommended** that the construction of engineered sea walls or other forms of coastal defense, such as breakwaters (wave breakers) are **not** an appropriate coastal management, or cost effective solution, for reducing the risks posed by coastal erosion, flooding and storms around **much** of the coastline of Kosrae.

2. Table 6 details the locations where the construction or upgrading of existing defenses is the most appropriate long term coastal management strategy for the protection of infrastructure or property. The table also lists a number of critical areas where the construction of coastal defenses has been suggested but cannot be recommended.

Location	Length of Defense km (miles)	Urgency	Details of required coastal defense work
TAFUNSAK			
Walung	-		Sea walls or other forms of coast protection will not reduce the flooding problems or protect properties located close to the coastline
Wiya	0.3 (0.2)	Low	Rock revetment protection for road around corner towards Malsu.
Finfukal	0.2 (0.13)	High	Completion of rock revetment and rock sill at western end of revetment. The erosion problems and risk to the road between Sialat and Yekula are likely continue along sections of the coastline at either end of the planned coastal defenses. In the longer term coastal defenses are not a cost effective option in protecting the road along this section of coastline.
LELU			
Sandy Beach			*Although a proposed scheme for alleviating the erosion problems at Sandy Beach has been developed, it is unlikely that the scheme is economically justifiable.*
Putuk		Low	Replacement of vertical concrete seawall by sloping rock rip rap revetment, founded on reef flat with beach replaced on the seaward side of the structure. However, mangrove planting could provide adequate protection to the road along this section of coastline.
Causeway	0.75 (0.5)	Medium	Upgrading the protection along the east face of the causeway (mainly replacing and regrouting rock in place)
North Lelu	1.0 (0.63)	Medium	Upgrading existing defenses to protect road – some rock rip-rap along new sections, some regrouting of coral block walls (in addition to potential mangrove replanting)
South Lelu (Fihkihil to Otnaur)	0.8 (0.5)	High	Upgrade existing coral blockwork sea wall with rock armour between Farmer's Market & Jacob Nena's property.
South Lelu (Fihkihil to Lelu Church)	1.4 (0.9)	Medium	Upgrade existing coral block walls – regrouting, toe protection and patching up. If further funds are available – recommend the ongoing replacement of coral block walls with sloping rock revetments
Tafuyat	0.2 (0.13)	Medium	Rock rip rap protection for road (in addition to mangrove replanting)
Leyot / Mutunlik	1.2 (0.75)	High	Complete rebuilding of coastal defenses protecting the road at Leyot / Mutunlik. A sloping rock revetment is recommended.

Table 6 Future coastal defense requirements

Location	Length of Defense km (miles)	Urgency	Details of required coastal defense work
MALEM			
Malem village	0.6 (0.38)	High	Completion of 5 semi submerged rock breakwater to the north of the Malem River outlet. Completion of the rock revetment at the mouth of the Malem River – raising elevation of rock armor above existing land levels. Completion of rock revetment south of the Malem River – one more layer of rock (at least 2 rocks wide) along the crest of the revetment. Completion of the end of the defense no further south than ER Store.
Kotfwa & Pal			*Economically justifiable coastal defenses are unlikely to prevent flooding of the property and overwashing of the road and may exacerbated erosion along the coastline to the south.*
UTWE			
Inpuspusa			*Although the road is being undercut at the Malem / Utwe Municipality boundary, sea walls or other coastal defenses along short sections of this coastline are likely to cause increased erosion along adjacent sections. It is recommended that the road be re-aligned further landward along this short section.*
Utwe Village	0.5 (0.32)	Low	Upgrading existing coral block walls – regrouting, patching up, toe protection where necessary. If more substantial funds are available – replacement of coral block wall with sloping rock revetment.
TOTAL	**6.95km (4.44 miles)**		

Table 6 cont. Future coastal defense requirements.

The expected cost of adequately addressing the sections with a high urgency for the repair, upgrading or provision of coastal defenses is in the order of $1 – 2 million dollars.