RESPONDING TO CLIMATE CHANGE IN MOZAMBIQUE

Instituto Nacional de Gestão de Calamidades

National Institute for Disaster Management (INGC) PHASE II

THEME 2
COASTAL PLANNING AND ADAPTATION TO MITIGATE CLIMATE CHANGE IMPACTS

ADAPTATION RECOMMENDATIONS:

INHAMBANE / MAXIXE / TOFO / BARRA

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(Note: Serving as the background and context, below is a copy of the Executive Summary from the Theme 2 Full report (INGC, 2012). The full report is available in the Repository section of the portal)

EXECUTIVE SUMMARY

S.1 BACKGROUND

Mozambique is recognized as one of the countries in Africa that is most vulnerable to climate change. Hazards such as droughts and floods, variable rainfall and tropical cyclones already significantly affect the country.

The country's coastal zone is particularly vulnerable to the expected impacts of climate change. Contributing factors include:

- Vast low-lying coastal plains such as delta coasts;
- High population concentrations in close proximity to the sea;
- Poverty;
- Low capacity to defend infrastructure;
- Susceptibility to cyclone activity;
- Soft erodible coasts; and
- Inadequate and ageing coastal defences.

This situation is aggravated by direct exposure to high wave energy regimes in some parts, a potential increase in cyclone impacts, and impacted natural coastal defences such as dunes, mangroves and coral reefs. Large numbers of the local population also rely heavily on goods and services and economic benefits provided by the coastal zone.

In this regard, the National Institute for Disaster Management (INGC) initiated two studies to define and locally contextualise important drivers and impacts of climate change in the country. Phase I, completed in 2009, focused on determining the impacts of climate change on Mozambique at the macro level. The current project, Phase II, focuses on both the macro and the micro levels, with an emphasis on the implementation of adaptation measures and providing strategic and scientific evidence-based guidance for decision-making.

Led by the Mozambican government, the overall goal of the Phase II project is to help protect the country against the potential impacts of climate change, and to plan for and kick start prevention through the implementation of adaptation measures at national scale, on the basis of science and in support of sustainable development.

As such, a multi-disciplinary group of scientists from Mozambique and other institutions formulated 9 themes to encapsulate the research challenges faced, namely:

- *Theme 1*: Early Warning at a Different Scale
- *Theme 2*: Coastal planning and adaptation to mitigate climate change impacts
- *Theme 3*: Cities prepared for climate change
- *Theme 4*: Building resilience in partnership with the private sector
- *Theme 5*: Water – doing More with less
- *Theme 6*: Food – Meeting demands.
- *Theme 7*: Preparing People
- *Theme 8*: Extremes
- *Theme 9*: National Strategy: 'Climate Change and Disaster Risk Reduction"

While this study is primarily concerned with Theme 2, it is closely aligned with Themes 3 and 4, and addresses the following key questions:

- Where are the most vulnerable areas along the coast, at the local/micro level?
- What will these areas look like, with climate change, in future?
- Which key infrastructure and future investment plans are at risk in these areas?
- What recommendations are in order for planned investments along the coast, with emphasis on Beira and Maputo?
- What structural coastal protection measures are needed to compensate for the potential effects of climate change?
- What shoreline management plans are most appropriate for these areas?
- What should be the strategic framework on which all coastal structures and sea defences can be evaluated?
- What should go into a coastal zone information system?
- What input can be provided for in a coastal management policy?

The INGC also emphasised the need for a pro-active approach to protect lives and infrastructure, while at the same time finding sustainable solutions that are durable and low cost.

S.2 KEY CONSIDERATIONS AND FINDINGS

S.2.1 Drivers of change

In Theme 2 the physical factors that influence the risk to coastal infrastructure in current and future climate scenarios were identified. This included consideration of the current situation along with future sea-level rise scenarios of 0.5m, 1.0m or 2m by 2100. These are further considered both with and without taking cyclones into account and the consideration of possible increases in "storminess" being another component of climate change.

The primary hazards to physical (abiotic) coastal infrastructure related to sea storms and climate change are:

- Extreme inshore sea water levels resulting in flooding and inundation of low lying areas.
- Changes in cyclone characteristics, winds and local wave regime resulting in direct wave impacts.
- Coastal erosion and under-scouring of, for example, foundations and structures.
- System complexities, thresholds and non-linearities, for example related to sand transport.
- A combination of extreme events, such as sea storms during high tides plus sea level rise, will have the greatest impacts and will increasingly overwhelm existing infrastructure as climate change related factors set in time.

The main drivers of change related to the above are thus waves and sea water levels (and to a lesser extent winds and currents). A detailed discussion are contained in a separate document available on the project portal..

The shoreline response and flooding impact is influenced by coastal parameters/processes such as: topography, geology, inshore wave action, sea level (including the tidal state and future rise), bathymetry and foredune volume.

To be of more use in hazard quantification and ultimately in finding ways of reducing risks and deriving practical adaptation measures, it is necessary to be able to predict or forecast the coastal response and severity of impacts. To this end, given the lack of historic data and information along the Mozambican coastline, three flooding scenarios are defined to establish the hazard levels at the specific sites in terms of possible flooding due to the various factors associated with 'normal' meteorological factors as well as the effects of climate change.

These three flooding level scenarios were calculated for each of the study towns and cities as depicted in the figure below (*the 3 bars for each town)*.

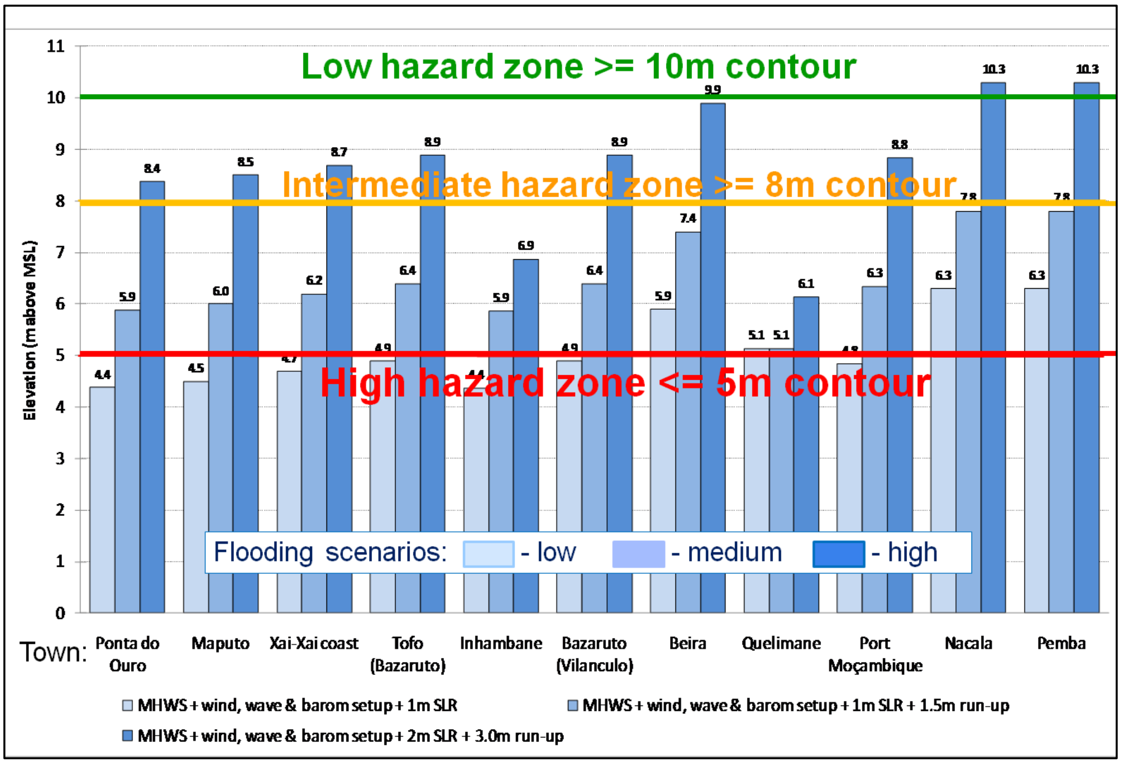
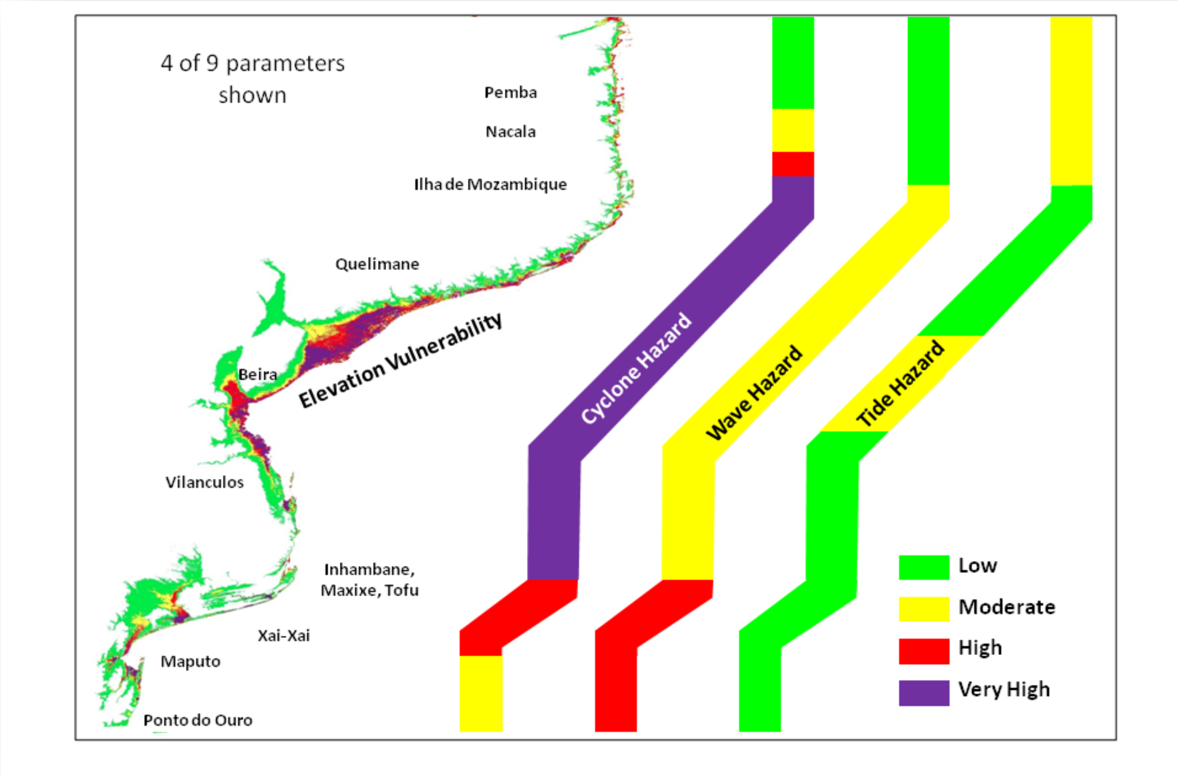


Figure 1: Coastal flooding levels for 11 towns/cities (Figure 6.3 in Full Report)

S.2.2 Coarse scale coastal vulnerability assessment

Broadly speaking, the low lying central delta coast areas (e.g. Beira) are very vulnerable in terms of elevation (see Figure below). The highest occurrence of cyclones (very high hazard) is found along the central parts of Mozambique, tapering off to the south (from roughly Tofo) and also sharply to the north (from about Ilha de Mocambique).



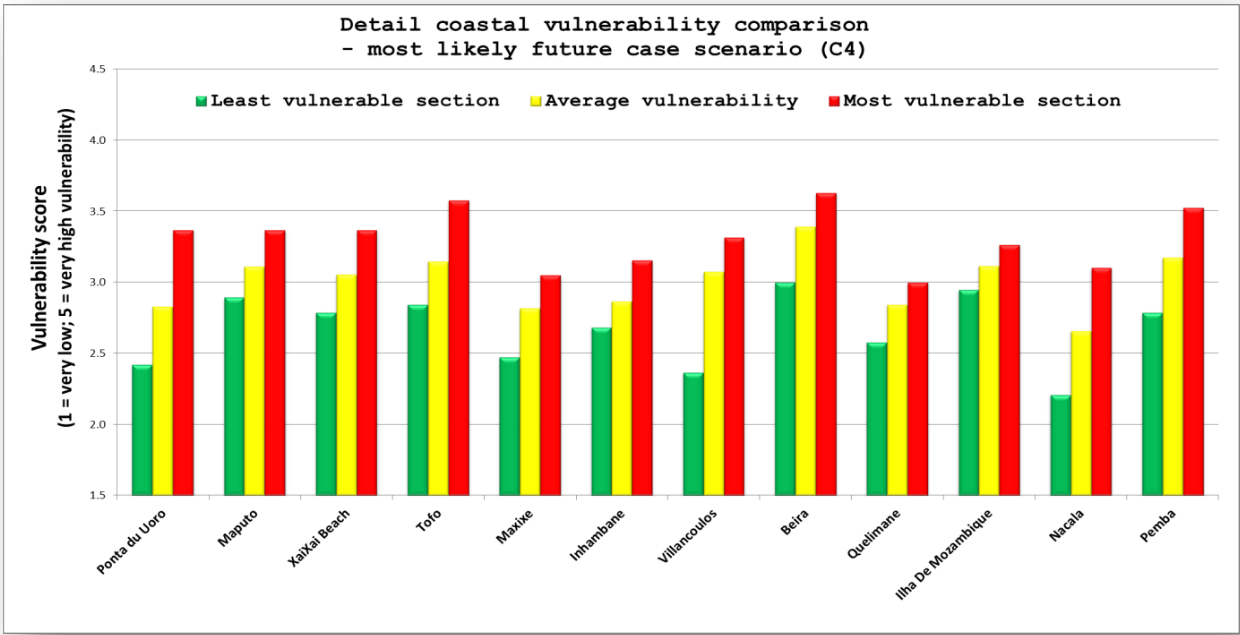
Coarse overview of hazards and vulnerability of Mozambican coast

S.2.3 Local / micro scale coastal vulnerability assessment

Analyses were carried out to determine the vulnerability of key coastal cities and towns (identified by the INGC) to the impact of a range of biophysical change scenarios.

The vulnerability to the forces from the sea of approximately 10 km of shoreline at each site was assessed by evaluating 14 abiotic parameters against an agreed to set of criteria. The vulnerability assessment was done with and without climate change factors, and also with and without the effect of cyclones. Total vulnerability maps are available for each of the study sites, for the 8 scenarios that include cyclones (i.e. C1 to D4).

The figure below shows the detailed coastal vulnerability comparison of the 12 coastal study sites when the most likely future climate change scenario, C4, is used. (Scenario C4 considers a 1m sea-level rise by 2100 and includes both the effects of cyclones and an increase in storminess due to climate change.



A comparison of the vulnerabilities of the 12 study sites under the most likely future case scenario (C4)

Results show that the most vulnerable towns are Ponta do Ouro, Maputo, XaiXai Beach, Tofo, Villanculos, Beira and Pemba. Beira is identified as the most vulnerable city.

S.2.4 Appropriate adaptation measures

A comprehensive literature review led to the identification of a number of management options and "soft" and "hard" coastal engineering methods available to protect the shoreline (Section 7.2, pages 127 – 148 of the full report – INGC, 2012, also available as a separate document on the project portal).

By considering the coastal processes and characteristics of the study area, and factors governing suitability for coastal development, various potential response options were identified.

Based on the foregoing evaluation considerations and criteria, and including all appropriate options, the priority adaptation/"no-regret" measures were grouped according to type and impact, covering the most relevant climate change issues for Mozambique coastal towns and cities.

The results together with site investigations allowed coastal engineers to determine the most appropriate adaptation options to introduce for a particular area within the study areas. Following a conservative and precautionary approach, a list of prioritised adaptation response actions for each town and city was recommended. These are available as separate documents for each site.

The following potential options to respond and adapt to the impacts of climate change have been identified for the study areas.

A "Management options"

A1 "Accept and retreat": repositioning infrastructure at risk; zoning, set-back lines, resettlement, etc.

A2 "Abstention" involves the 'do nothing' option. (If the risk of loss of property or human life is very minimal.)

A3 "Alternative" coastal developments: develop "safe" alternative coastal areas including services.

A4 "Accommodation": increase resilience and accommodate impacts on infrastructure e.g. raising property.

B "Soft engineering" or Restoration
("semi-natural" interventions in the littoral zone)

B1 Sand nourishment: pump extra sand onto the beach to build it up and reduce wave impacts & flooding.

B2 Managed (vegetated and/or reinforced) dune. Construct/reinstate and/or manage vegetated dune areas.

B3 Mangroves, corals and wetlands. Expand/reinstate and manage/protect such natural defences.

C "Hard engineering" & armouring
(construct shore protection measures)

C1 Seawalls (C1s) & revetments (C1r): sloping, vertical or curved concrete/rock structures.

C2 Dikes: massive sloped (landscaped and vegetated) loose standing sand/ earthen mound.

C3 Perched beach structures: artificially keep the upper part of the beach profile in place

C4 Shore-parallel structures (e.g. artificial surf zone reefs, detached breakwaters, rock berms, etc.).

C5 Groynes (straight, curved, T, L etc.) placed perpendicular or at angle to shoreline, can trap sediment

C6 Spending beach of very coarse sand, gravel or cobbles: dissipates wave energy & erosion.

C7 Beach (and dune) dewatering mechanism. Sediment "stability" can be increased

C8 Coastal flood control gates in "enclosed" areas (e.g. river mouths, small bays).

In low to moderate wave energy environments:

C9 Closely spaced piles or wave fences to dissipate wave energy.
C10 Floating moored "breakwater" type structures.
C11 "Geotextile" shore protection, usually sand filled geotextile containers.
C12 Gabions and/or rock filled wire basket & mattress structures.

D Combined options

A combination of two or more of the identified solution options may be required.

S.3 KEY CONSIDERATIONS AND FINDINGS

S.3.1 Integrated coastal planning and management

The adoption and implementation of the strategic principles and guidelines on planning for and responding to coastal impacts and including specifically climate change impacts is seen as the first and most important action point.

Most of the response options are purposefully what can be termed "soft" options or "working with nature". Following an integrated coastal planning approach is in line with strategic principles and best practise guidelines in terms of coastal management and responding to climate change. This simple management level decision will go a long way in reducing the need for constructing expensive coastal defences in many instances, especially in the long-term. Activities are, amongst others:

- Plan any coastal construction so that it is a safe distance away from the high-water mark and reinstate natural defence mechanisms with the necessary environmental authorisations.
- Undertake holistic planning and implementation through the development and implementation of Coastal Management Programmes that incorporate Shoreline Management Plans.
- Establish a coastal development setback line which is designed to protect both the natural environment from encroachment from buildings as well as protecting beachfront developments from the effects of storms and accelerated coastal erosion.
- Work with nature by protecting the integrity of buffer dune systems, which should be vegetated with appropriate dune species as per the original natural zones and maintained.
- Maintain, or even better, increase the sand reservoir (volume) stored in the dune system.
- Protection, restoration and maintenance of natural systems like mangroves and coral reefs.

S.3.2 Monitoring and evaluation requirements

Establish a baseline

Following on the present Phase II work, it is expected that there will be an implementation phase. In any follow up phase of work, it is essential to include as priority additional data collection and monitoring to address the critical gap in regional, national and local level data and information required to enable detailed planning and design and to increase the level of confidence in the key sets of information on which the adaptation measures identified in this study are based.

The parameters and issues which should be monitored include the following:

- ✓ Cyclone characteristics – done when appropriate.
- ✓ Winds and local wave regime (and sea storms) – ongoing.
- ✓ Inshore sea water levels (tides and sea level trends) - ongoing
- ▪ Shoreline stability and trends (erosion/accretion)- a baseline survey as soon as possible followed by repeat surveys every three to five years, and after each major cyclone.
- ▪ Integrity of built coastal defences/structures - a baseline survey followed by repeat surveys every three to five years. This should be a critical input into an effective infrastructure maintenance plan.
- ▪ Integrity of natural coastal defences (dunes, mangroves, coral reefs, wetlands) – a baseline followed by regular repeats as appropriate. This should also be a critical input into an effective maintenance and wider integrated coastal zone management plan.
- ▪ It is of utmost importance to collect sufficiently detailed topographic and bathymetric data at identified priority areas. This can mostly be a "once off" baseline data collection task, but should be repeated at longer intervals, perhaps every 10 years for the topographic data, or immediately after any major change caused by, for example, a cyclone that will then form the new baseline.

As far as can be determined, the first three items (indicated by a tick) are being monitored to some degree or can be derived indirectly from existing monitoring actions. However, the last four items (indicated by a square dot) are not being monitored (as far as it is known). These items are also critical for any proper integrated coastal zone management and sustainable coastal developments assessments and plans. Thus, it is strongly recommended that actions be taken to ensure that effective monitoring of all the above mentioned parameters is undertaken.

As indicated, while some of the parameters need to be collected at very short time intervals (e.g. sub-hourly wind data), others need only be collected every few years (e.g. topographic data).

Ongoing monitoring, evaluation, dissemination and response

Building onto the recommendation on decision-support that arose through the interaction with stakeholder groups, it is considered of strategic and tactical importance to implement a national programme of ongoing monitoring and reporting of key environmental indicators that are relevant to the climate change parameters identified during this study.

The INGC has a well established and proven network for near real-time information gathering, evaluation and response during the lead up and in emergency events, such as cyclones, floods, fires etc. It is therefore recommended that a complementary network for data gathering, evaluation and information dissemination regarding climate change effects, possible trends in the identified hazard drivers, and resulting impacts to build up the scientific database and knowledge on which informed decisions can be made be set up as soon as possible.

(Note: This is an extract from the Theme 2 Full report (INGC, 2012) Section 8, pages 154 -181. The full report is available in the Repository section of the portal)

ADAPTATION OPTIONS: INHAMBANE, MAXIXI, TOFO & BARRA

Before going into the detailed adaptation recommendations for each city/town, it is important to reiterate that **the strategic principles and guidelines on planning for and responding to coastal impacts and including specifically climate change impacts, as discussed in Section 7.1 of the Theme 2 full report (INGC, 2012), should be adopted and implemented forthwith**. This will go a long way in reducing the need for constructing expensive coastal defences in many instances, especially in the long-term.

SITE SPECIFIC ANALYSIS AND RECOMMENDED PRIORITIZED ADAPTATION ACTIONS

The derivation of final recommendations for site specific 'no regret' adaptation measures entailed the following tasks/actions:

- A literature survey (Chapter 7 of the full report)
- Assessment against the evaluation considerations and criteria (Section 7.3)
- Use of coastal engineering practice and experience
- On site observations and surveys during a field mission to each site in May 2010
- Consensus within a multi-disciplinary coastal specialist team

Following a conservative and precautionary approach with the aim to be pro-active and prevent or lower the risk to lives, livelihoods and infrastructure, a list of prioritized adaptation response actions for each town and city was derived and is provided in the form of annotated diagrammes on Google-Earth$_{TM}$ images (Figures 8.1 to 8.17). The specific engineering design details and accurate costing of each option can only be done once site specific engineering and environmental investigations have been carried out. It is absolutely critical to involve experienced coastal engineering and coastal environmental professionals in the detailed planning, design and implementation of the chosen options.

The results for the city are discussed in Section 8 in the full report and summarised below. The results for the other study sites are presented in a similar manner in separate documents.

Inhambane & Maxixe: elevation hazard

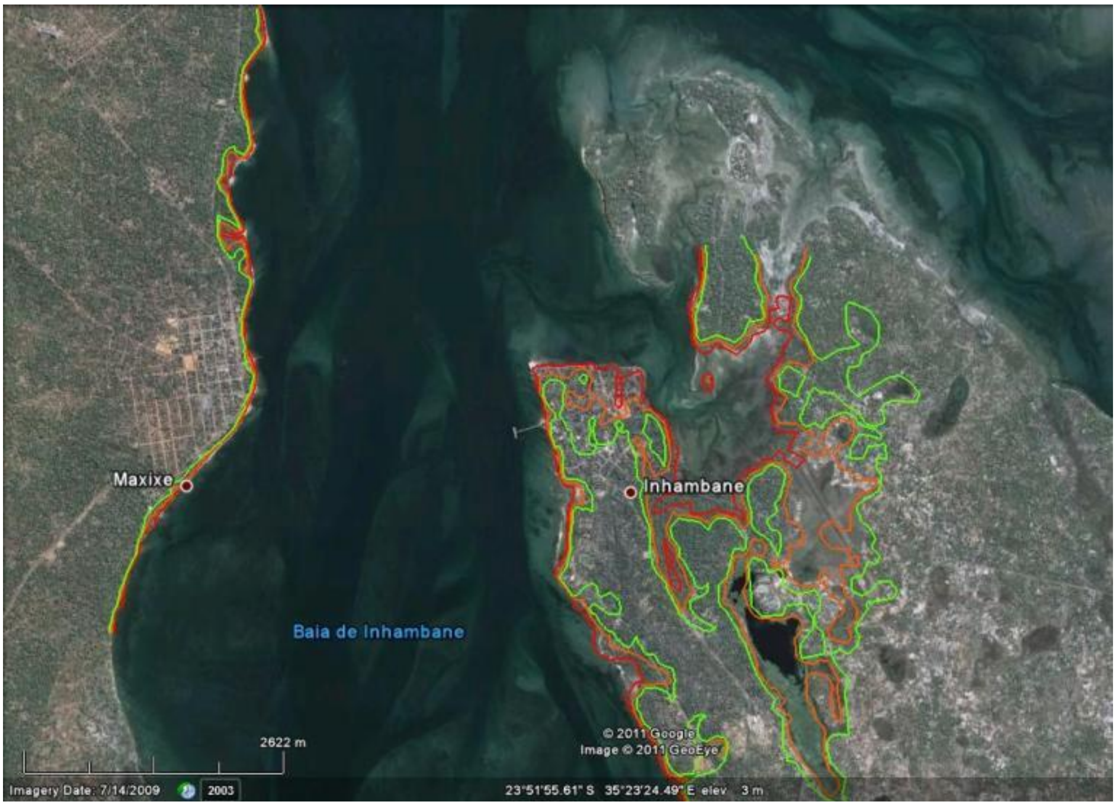


Figure 2: Estimated contours for Maxixe; Inhambane (Figure 6.9 in Full Report)

The Maxixe and Inhambane shorelines are only semi-exposed to cyclone waves (approaching from the NE). Thus, wave run-up is not expected to exceed about 1.5 m. The intermediate flooding hazard level of +5.9 m MSL is mostly applicable. Critical infrastructure (100 year planning horizon) should only allow for an additional 1 m of SLR (i.e. 2 m SLR in total) by 2100, thus giving a "design" level of +6.9 m MSL.

Tofo & Barra: elevation hazard

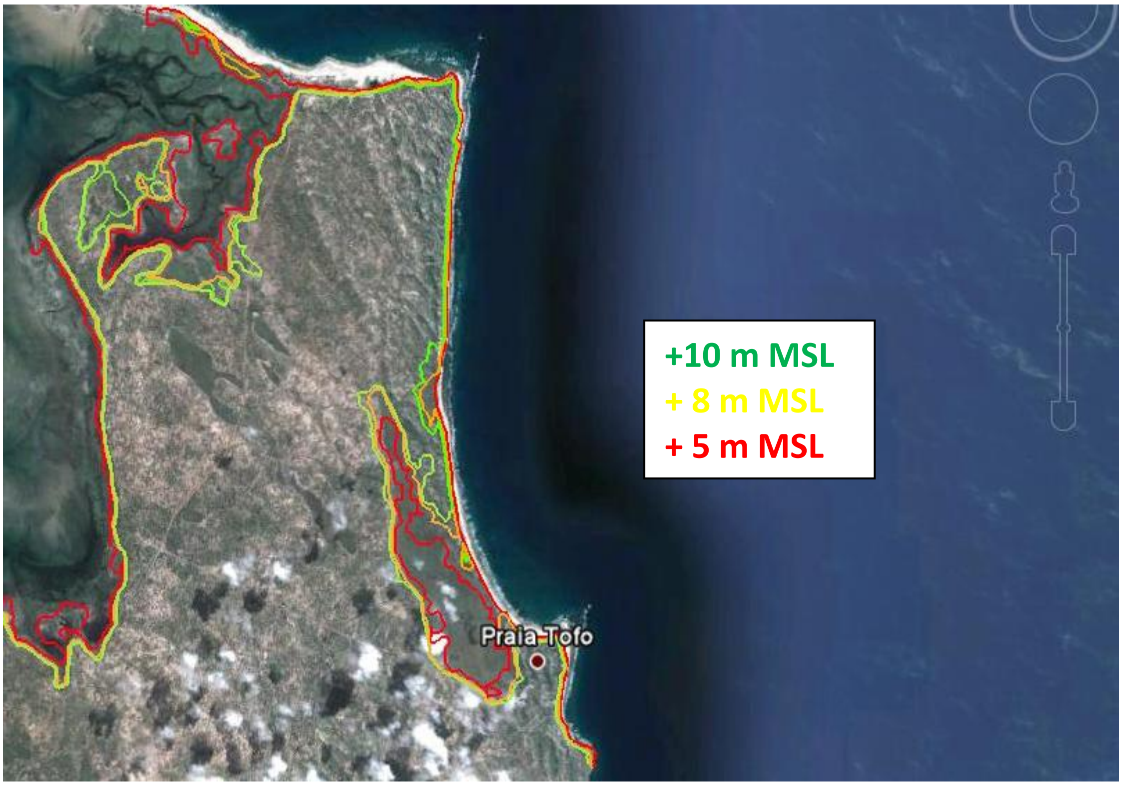


Figure 3: Estimated contours for Tofo / Barra (overlain on Google Earth image) (Figure 6.8 in Full report)

Most of the Tofo area is fully exposed (Figure 3). The northern shore at Barra is generally less exposed to wave action, but this area is directly exposed to cyclone waves approaching from the NE. Thus, flooding levels of +6.4 m MSL and +8.9 m MSL are applicable for the intermediate and extreme flooding scenarios respectively. The coastal topography is relatively steep with high ground relatively close to the sea, expect for two extensive low-lying wetland areas which are susceptible to flooding from the sea.

Inhambane & Maxixe: adaptation options

Referring to the discussions in Chapters 5 and 6 (Full Report), the “sea water flooding hazard” levels for the Inhambane and Maxixe area (Figure 1) show that for a 1m sea level rise (by 2100) plus a run-up of +1.5 m during cyclonic events, that areas below the +6 m contour will be in danger of being flooded. The extensive sandbanks seaward of Inhambane and Maxixe provide partial shelter from the full extent of wave impacts such as extreme flooding levels. Thus, the intermediate flooding level of +6 m MSL is appropriate for planning and management of infrastructure along the shoreline with a design life of less than 50 years. Due to the partial wave sheltering, extreme wave runup is not expected to exceed the 1.5 m already allowed for in the +6 m MSL flooding level. However, taking a conservative and precautionary approach, the extreme scenario of 2 m SLR by 2100 should be considered. Thus, the low hazard risk level for important infrastructure with a design life of more than 50 years such as airports is +7 m MSL (as the extreme scenario of a +2 m sea level rise along with a 1.5 m storm run-up level during cyclones).

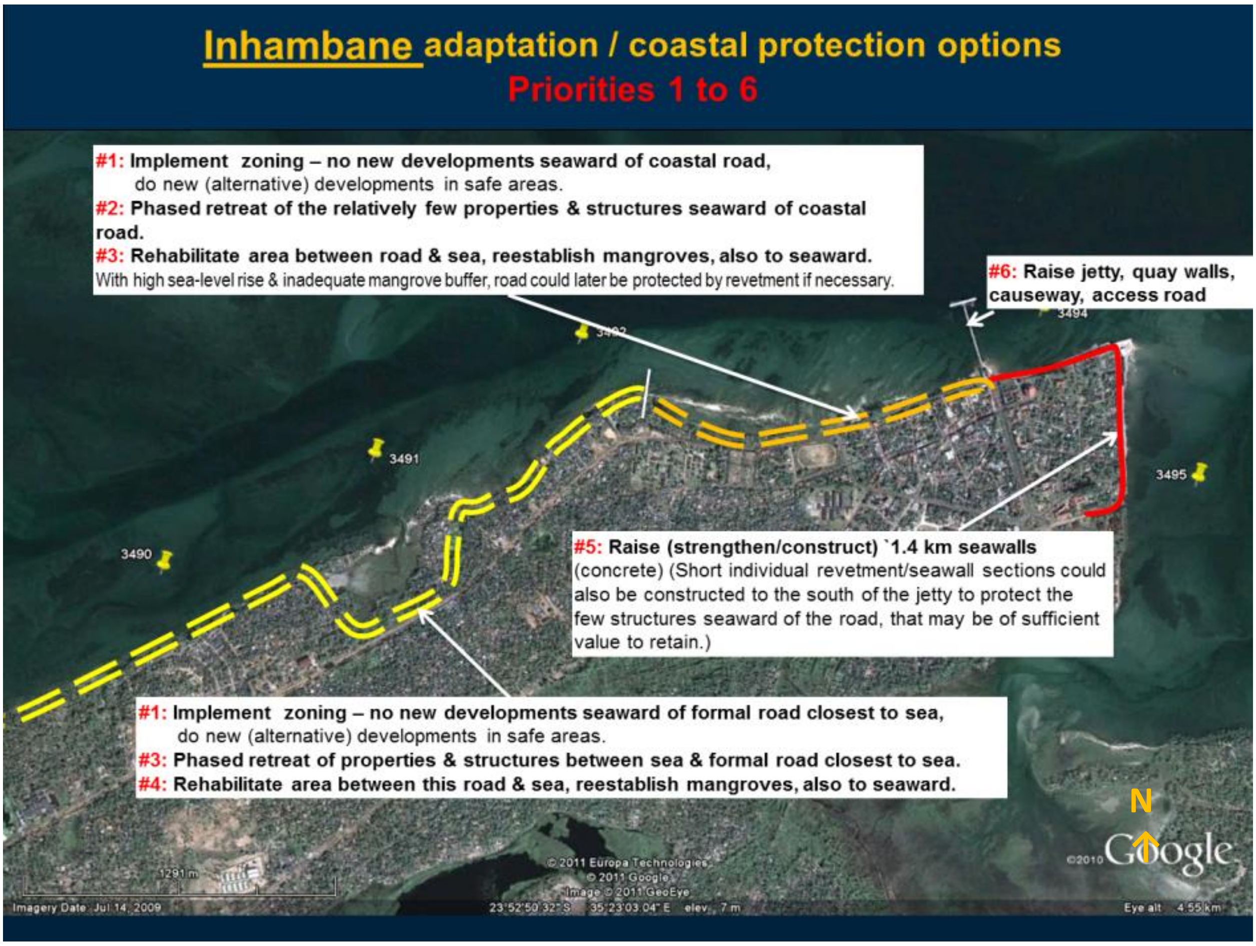


Figure 4: *Inhambane. Recommended adaptation /coastal protection options (Figure 8.11 in Full Report)*

As can be seen in Figure 4, and referring to the suite of adaptaion options provided in Section S.2.4 above, the only real affordable long term option to adapt to the effects of climate change is to ensure that development is located beyond the reach of the natural processes (A1). This can be achieved by implementing zoning to prevent development from taking place below the + 7 m MSL contour level (Priority #1). (For "greenfield" or undeveloped areas, this more conservative level allowing for 2 m SLR is recommended.) Gradual relocation (A3) of existing development to alternative safer areas should be included in the Structure Plan (Priorities #2 and #3). The active rehabilitation (B3) of mangrove areas (Priority #3 and #4) will form a natural barrier against storm waves and surges (flooding).

Much of the historical area to the north of the town is very low-lying and at serious risk of being flooded under the climate change factors. Other than retreating from the area (A1 & A3) as the storm surges become more threatening in time, more costly hard-engineering options (C1s, C1r and/or C2) will be the only solution in the long run. Options for forming Public-Private-Partnerships (PPP) type of development could be considered and new developments should be designed to cater for the climate change factors and also to assist the municipality with the required adaptation works.

Although the current jetty has recently been upgraded, the raising or reinforcement of areas may be necessary in the far future (A4).

Of greater concern is the fact that the current international airport is in a low-lying area and adequate protection of the runway as well as the other infrastructure should be incorporated in any future redevelopment or upgrading plans (possibly C2 supported by B3 and A4).

(In the greater Inhambane region, there are many coastal lakes around which people live, in some instances in vulnerable locations. This is however beyond the scope of the present investigation, which focuses more on specific urban centres and surrounds located along and close to the influence of forces from the sea).

Tofo and Barra: adaptation options

The "sea water flooding hazard" levels for the Tofo/Barra area (Figure 1) show that for a 1m sea level rise (by 2100) plus a run-up of +1.5 m during cyclonic events, that areas below the +6.5 m contour will be in danger of being flooded. This intermediate flooding level of +6.5 m MSL is appropriate for planning and management of infrastructure along the shoreline with a design life of less than 50 years. The low hazard risk level for important infrastructure is +9 m MSL (rounded up from 8.9 m MSL) as the extreme scenario of a +2 m sea level rise along with a 3 m storm run-up level during cyclones.

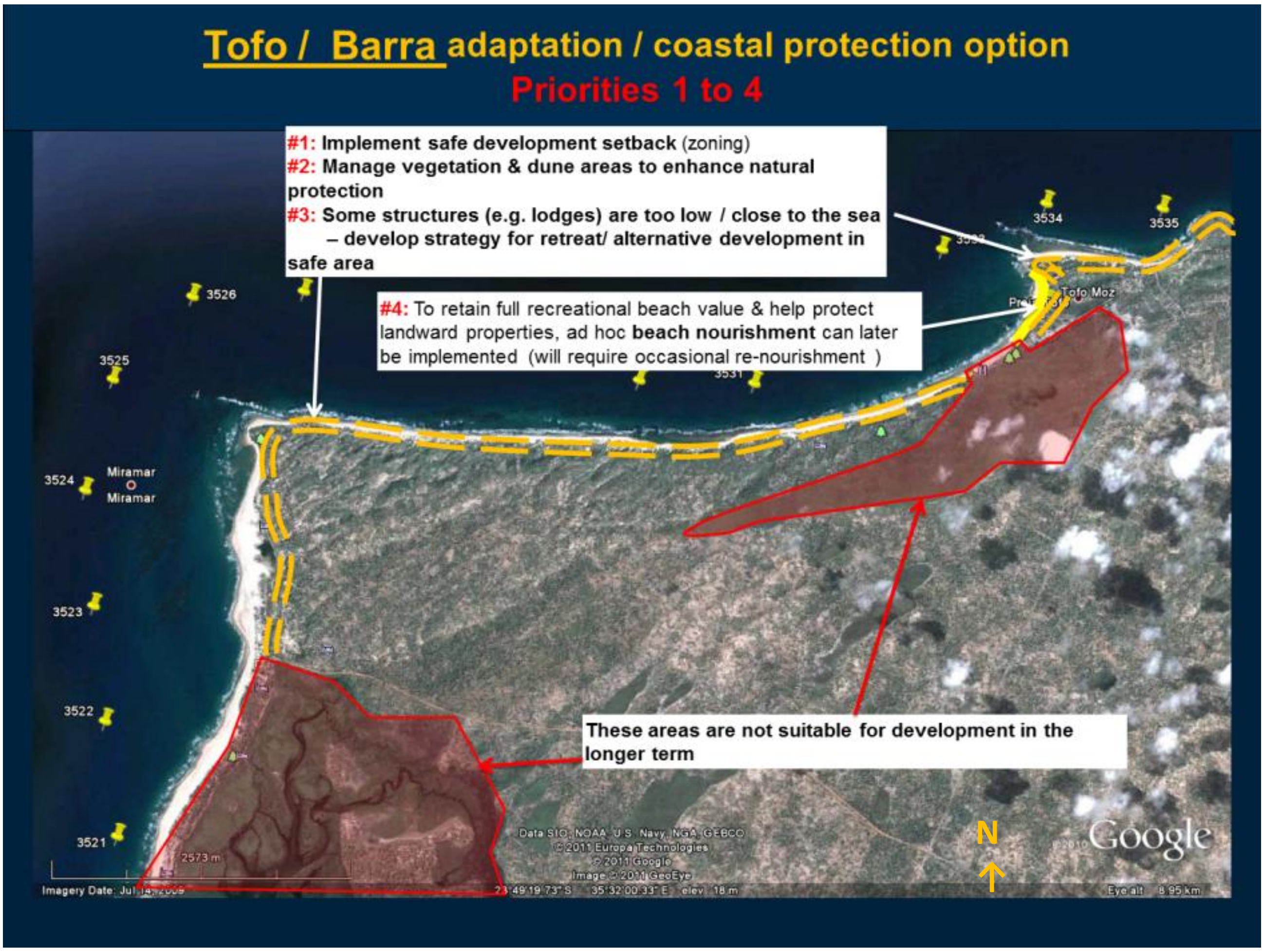


Figure 5: Tofo & Barra. Recommended adaptation /coastal protection options (Figure 8.12 in Full Report)

As can be seen in Figure 5, the only real affordable long term option to adapt to the effects of climate change is to ensure that development is located beyond the reach of the natural processes (A1 & A3). This can be achieved by implementing zoning to prevent development from taking place in the hazard zone (Priority #1). For the open Tofo coast, which is exposed to high wave run-up, this 'no-development zone' is typically above the + 9 m MSL contour level and a minimum of 100 m from the high water mark. (For "greenfield" or undeveloped areas, this more conservative level allowing for 2 m SLR is recommended.)

Priority #2 is seen as the active rehabilitation of damaged foredunes and the conservation of the dune vegetation and volume (B2) will ensure that a natural barrier against storm waves and surges (flooding) is maintained. Gradual relocation of existing low-lying development to alternative lower risk areas (A1 & A3) should be included in the Structure Plan (Priority #3).

THE REHABILITATION OF MANGROVE AREAS (B3) TO FORM EFFECTIVE NATURAL BUFFER AREAS ALL ALONG THE INNER SHORELINE OF THE BAY SHOULD BE ENCOURAGED AND COULD BE AN EXCELLENT JOB CREATION OPPORTUNITY. CONCLUSION

In addition to the recommendation that the strategic principles and guidelines on planning for and responding to coastal impacts and including specifically climate change impacts as discussed in Section 7.1, should be adopted and implemented forthwith, site specific analysis and recommended prioritised adaptation options for each of the study sites were presented.

Noted is that the specific engineering design details and accurate costing of each option can only be done once site specific engineering and environmental investigations have been carried out where it is absolutely critical to involve experienced coastal engineering and coastal environmental professionals in the detailed planning, design and implementation of the chosen options.

In most cases sound planning and future development beyond the reach of the sea forces can be implemented successfully. Many opportunities for entering into PPP exist which has the potential to co-fund the implementation of the more costly “hard”-engineering adaptation options

KEY RECOMMENDATIONS

Integrated coastal planning and management

The adoption and implementation of the strategic principles and guidelines on planning for and responding to coastal impacts and including specifically climate change impacts, as discussed in Chapter 7 is seen as the first and most important action point. Most of the response options are purposefully what can be termed “soft” options or “working with nature”. Following an integrated coastal planning approach is in line with strategic principles and best practise guidelines in terms of coastal management and responding to climate change. This simple management level decision will go a long way in reducing the need for constructing expensive coastal defences in many instances, especially in the long-term. Activities are, amongst others:

- Plan any coastal construction so that it is a safe distance away from the high-water mark and reinstate natural defence mechanisms with the necessary environmental authorisations.
- Undertake holistic planning and implementation through the development and implementation of Coastal Management Programmes that incorporate Shoreline Management Plans.
- Establish a coastal development setback line which is designed to protect both the natural environment from encroachment from buildings as well as protecting beachfront developments from the effects of storms and accelerated coastal erosion.
- Work with nature by protecting the integrity of buffer dune systems, which should be vegetated with appropriate dune species as per the original natural zones and maintained.

- Maintain, or even better, increase the sand reservoir (volume) stored in the dune system.
- Protection, restoration and maintenance of natural systems like mangroves and coral reefs.

Seek opportunities for public-private-partnerships (PPP)

In many cases sound planning and future development beyond the reach of the sea forces can be implemented successfully. Many opportunities for entering into 'design-&-build' type PPP exist which have the potential to co-fund the implementation of the more costly "hard"-engineering adaptation options.

Continue active engagement and communication with stakeholders to disseminate the outputs and facilitate uptake

Observations by the study team during interaction with stakeholder groups at various levels of authority leads to the following recommendations presented for consideration:

The recommendations fall into three categories, namely (a) those that relate to the various decision-makers, (b) those at a more technical/scientific level, and (c) those that relate to decision-making.

(a) Leadership aspects

The following actions can be implemented immediately and maintained on an ongoing basis:

1. Local leaders (Authorities as well as Traditional) should be encouraged to respect the fact that climate change may lead to a threat to lives, livelihoods and infrastructure.

2. Leaders should be encouraged to endorse the adoption and application of the strategic principles and best practice guidelines for adaptation measures (Section 7.1) in all Integrated Coastal Zone Management, coastal governance and planning of coastal developments.

3. Leaders should be encouraged to implement the prioritised "no-regret" adaptation measures as soon as possible. In most cases this means adhering to sound planning and design principles.

4. Leaders should be encouraged to incorporate the results of the studies into the current and future plans such as municipal structure plans and public and privately funded development plans.

5. Leaders should be encouraged to consider following a PPP approach to obtain co-funding for the more costly but critically important adaptation measures.

(b) Technical and scientific aspects

The following technical and scientific aspects are recommended for immediate implementation over the next 6 to 12 months:

1. Due to the importance of knowing the actual elevation of the identified high risk areas, it is of utmost importance to carry out detailed topographic surveys of the coastal strip in all towns and cities.

2. The current municipal structure plans and other development planning along the coastline should be updated to incorporate the identified climate change factors.

3. Approved coastal development plans should be revised to ensure the relevant climate change related factors are taken into consideration and that private developers are aware of the potential risk of not taking a precautionary approach. (Tourism could be one of the sources of income for implementation of adaptation measures.)

4. A formal system for monitoring, evaluating, and reporting on the key parameters identified in this study should be set up and maintained by a competent authority.

(c) Knowledge dissemination and decision Support

To enable informed, evidence based decision-making, the following actions can be implemented within 12 to 24 months:

1. Develop decision support tools such as maps, GIS database, reports and practical rule-based guidelines for use by the coastal management community at National, Provincial and Municipal levels.

2. Carry out a process to effectively disseminate results of this study at National, Provincial and Municipality levels. Also, embark on an information and education drive to raise wider local population awareness.

3. Establish a regional extension/advisory service. This can possibly be done via the INGC regional offices supported by relevant scientific, engineering and technological expertise located at the universities, relevant Ministries and in partnership with regional and international service providers until a national capability is established.

4. Introduce formal climate change adaptation related skills development programmes at all decision support levels (Management, Administration and Technical levels).

(Early warning systems (e.g. via cell phones), emergency response plans and measures for extreme events, such as cyclones, are not the focus of this investigation, but are obviously also of critical importance. The INGC has demonstrated good foresight and implementation in this regard in the past.)

MONITORING AND EVALUATION REQUIREMENTS

Establish a baseline

Following on the present Phase II work, it is expected that there will be an implementation phase. In any follow up phase of work, it is essential to include as priority additional data collection and monitoring to address the critical gap in regional, national and local level data and information required to enable detailed planning and design and to increase the level of confidence in the key sets of information on which the adaptation measures identified in this study are based.

The parameters and issues which should be monitored include the following:

- ✓ Cyclone characteristics – done when appropriate.
- ✓ Winds and local wave regime (and sea storms) – ongoing.
- ✓ Inshore sea water levels (tides and sea level trends) - ongoing
- ▪ Shoreline stability and trends (erosion/accretion)- a baseline survey as soon as possible followed by repeat surveys every three to five years, and after each major cyclone.
- ▪ Integrity of built coastal defences/structures - a baseline survey followed by repeat surveys every three to five years. This should be a critical input into an effective infrastructure maintenance plan.
- ▪ Integrity of natural coastal defences (dunes, mangroves, coral reefs, wetlands) – a baseline followed by regular repeats as appropriate. This should also be a critical input into an effective maintenance and wider integrated coastal zone management plan.
- ▪ It is of utmost importance to collect sufficiently detailed topographic and bathymetric data at identified priority areas. This can mostly be a "once off" baseline data collection task, but should be repeated at longer intervals, perhaps every 10 years for the topographic data, or immediately after any major change caused by, for example, a cyclone that will then form the new baseline.

As far as can be determined, the first three items (indicated by a tick) are being monitored to some degree or can be derived indirectly from existing monitoring actions. However, the last four items (indicated by a square dot) are not being monitored (as far as it is known). These items are also critical for any proper integrated coastal zone management and sustainable coastal developments assessments and plans. Thus, it is strongly recommended that actions be taken to ensure that effective monitoring of all the above mentioned parameters is undertaken.

As indicated, while some of the parameters need to be collected at very short time intervals (e.g. sub-hourly wind data), others need only be collected every few years (e.g. topographic data).

Ongoing monitoring, evaluation, dissemination and response

Building onto the recommendation on decision-support that arose through the interaction with stakeholder groups, it is considered of strategic and tactical importance to implement a national programme of ongoing monitoring and reporting of key environmental indicators that are relevant to the climate change parameters identified during this study.

The INGC has a well established and proven network for near real-time information gathering, evaluation and response during the lead up and in emergency events, such as cyclones, floods, fires etc. It is therefore recommended that a complementary network for data gathering, evaluation and information dissemination regarding climate change effects, possible trends in the identified hazard drivers, and resulting impacts to build up the scientific database and knowledge on which informed decisions can be made be set up as soon as possible.

REFERENCES & GLOSSARY

A comprehensive list references and a glossary of terms are included in the full Theme 2 report (INGC, 2012).

Reference:

INGC, 2012. National Institute for Disaster Management (INGC) Phase II: Theme 2: Coastal Planning and Adaptation to Mitigate Climate Change Impacts.