

**SEA-LEVEL RISE IN NAMIBIA'S
COASTAL TOWNS AND
WETLANDS: PROJECTED
IMPACTS AND RECOMMENDED
ADAPTATION STRATEGIES**

FINAL REPORT



Date: 11 September 2009

Prepared For:



Ministry of
Environment and
Tourism



UNDP Namibia

Prepared By:



Lithon
Project
Consultants

1. Executive Summary

1.1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992 as a global response to the threat of global warming. Namibia ratified the UNFCCC in 1995 as a Non-Annex I Party. As such, Namibia agreed to establish national programmes to slow climate change and to consider climate change within its development plans and activities for agriculture, energy, industry, natural resources, and the sea coast. The UNFCCC further recognises the vulnerability of developing countries such as Namibia to climate change, and it calls for efforts to assist developing countries to adapt to the expected impacts of climate change such as sea level rise.

This study was commissioned by the Ministry of Environment and Tourism (MET) for multiple reasons. First, Namibia will soon prepare its Second National Communication (SNC) to the UNFCCC; the findings and recommendations of this study will be incorporated into the SNC. Second, while Namibian stakeholders have been aware of global predictions for sea level rise, it is important that they are informed about the specific changes in sea level and storm surges that could be expected along Namibia's coast; this study addresses Namibia-specific conditions and scenarios. Third, it is important that Namibian stakeholders are informed about the possible impacts to Namibian property, infrastructure, water resources and ecosystems, and the options and recommended strategies for Namibia to adapt to those impacts; this study also addresses those needs. Finally, in addition to above reasons for commissioning this study, it is also envisaged that the MET would be able to use this study as a basis to apply to the Global Environment Facility for funding to support future programmes in Namibia to adapt to sea level rise and climate change.

The study includes four major sections. The first section (Section 4) is an assessment of the potential future changes in sea level rise along Namibia's coastline. The assessment considers several different scenarios and identifies the relative level of exposure of different coastal towns to sea level rise and storm surges. The second section (Section 5) is an analysis of the potential impacts to property, infrastructure and water resources. The second section includes a set of maps that indicate the areas within coastal towns that could potentially be impacted. The third section (Section 6) focuses on potential impacts to the Namibia's coastal wetlands and ecosystems. The third section also discusses issues of governance that are related to sea level rise. The fourth section (Section 7) is a comprehensive discussion of options and strategies to adapt to sea level rise.

1.2. Sea Level Rise Assessment (*by Professor Geoff Bundrit, LaquaR Consultants*)

In order to achieve the assessment, four studies were undertaken. The First Study provides a **Present Day Worst Case Scenario** of extreme sea levels for use in a Geographic Information System Inundation Model for the coastline of Namibia. This Scenario will result from the simultaneous occurrence of an extreme tide and an extreme storm, an event with a nominal return period of 100 years. The Scenario distinguishes between sheltered, exposed and very exposed coastal environments. The sea level due to the joint effect of the tide and the weather provides the sea level to be expected in sheltered environments along the coast of Namibia. In exposed coastal environments, particularly beach environments, wave set up needs to be added, whilst in very

exposed environments where deep water comes close inshore, wave run up also becomes important. For these two exposed environments, results from the extreme wave climatology of the Namibian coast need to be incorporated into the assessment. In summary, and using rounded values derived from sea level and wave observations at Walvis Bay and Luderitz, the maximum levels that should be expected to be reached by the sea along the coast of Namibia in this Present Day Worst Case Scenario are:

- LLD+1.5m in sheltered environments
- LLD+4m in exposed environments, and
- LLD+6m in very exposed environments.

LLD refers to Land Levelling Datum, which corresponds to Mean Sea Level. The levels expected in northern Namibia will be somewhat reduced, because of the less extreme wave climate in exposed and very exposed environments.

The Second Study provides the **Sea Level Scenario at 2030**, after the acceleration in sea level rise which is expected to add 20cm to base levels. Given the comparatively small rise in the sea level over this period, the levels to be used and the details of the inundation to be expected are the same as in Scenario One! It is how often these levels are expected that is different. The frequency with which the sea levels for exposed and very exposed environments are reached will depend upon the frequency expected for severe storms. It is possible that, with climate change, severe storms will become more frequent, and so the critical levels may well be reached more often in the future. On the other hand, the critical sea level of LLD+1.5m in sheltered coastal environments will definitely be reached more frequently. By 2030, these levels are likely to be reached every year.

In the longer term, up to 2100, the consequences of the onset of polar ice melt and sea level rise of several metres along the coast of Namibia are profound. Such a **Polar Ice Melt Scenario** forms the Third Study. The prime effect of the rapid sea level rise over the longer term future is the permanent inundation of low lying coastal areas, rather than the intermittent effect of storm damage, leading to the wholesale disruption of infrastructure and services along the coast. As there will be warning of such a huge sea level rise, and time to adapt, it will be important to plan ahead, explore the possible adaptation options and to put appropriate policies in place. Specific areas that will need attention are the implications for the onshore and offshore diamond industry, for coastal tourism, and for urban settlements such as Walvis Bay.

The Fourth Study follows the Sea Level Scenario at 2030, and explores the impacts of sea level rise along the coast of Namibia, particularly providing a **Sea Level Impact Scenario for Walvis Bay**. There are two quite different situations, which need to be considered separately. The first is if the protective Pelican Point Sandspit remains in place and the town and harbour of Walvis Bay remains a sheltered environment; and the second is if the Pelican Point Sandspit is breached and Walvis Bay is exposed to the full impact of storms from the sea. With the sandspit still in place in 2030, Walvis Bay will experience a sea level of LLD + 1.5m on an annual basis. Enhanced coastal erosion from the sea level rise of 20cm will lead to a likely coastal set-back estimated at almost 100m. Such levels of set-back may well not be acceptable, and so previously unprotected parts of the coastline may need to have new coastal defences built to prevent erosion close to the town of Walvis Bay itself.

With the protection of the Pelican Point sandspit removed, Walvis Bay can no longer be considered to be a sheltered environment. The town and harbour will be located on an open coast, exposed to greatly enhanced wave activity. With no additional protection, the town and harbour of Walvis Bay will be subject to sea levels of LLD+2m on an annual basis, and of LLD+3m from extreme sea levels with a return period of 100 years. Such an extreme sea level will inundate much of the town. The coastal defences needed to protect the town of Walvis Bay in this exposed situation, are much greater, extensive and costly than with the sandspit in place. It is clear that an assessment is needed of the measures that will ensure the continued viability of the Pelican Point Sandspit. Such an assessment should include a study of in-shore currents, local coastal topography and sand flows. Can the natural defences be sustained, or will it be necessary to turn to extensive coastal engineering? Future economic growth in Namibia will likely be a deciding factor in determining the appropriate approach by the authorities

1.3. **Impacts on Property, Infrastructure and Water Resources (by Danie Nel, Lithon Project Consultants)**

Based on the sea level assessment described above, three scenarios were compiled for the Namibian context, namely: the present day worst case, a scenario for year 2030; and three worst-case, forward looking predictions grouped under a scenario for an undetermined future date(s). It was established that there is a great deal of uncertainty with regard to the future expansion of urban areas along Namibia's coast. There is very little in the way of concrete medium to long term development planning against which impacts of damages and disruption incurred by sea level rise can be measured. Obtaining specific economic information, such as economic activity and volumes around the port areas as well as tourism was very challenging. This combined with the anticipated long term development of these scenarios led to increased emphasis on the potential damage and destruction of fixed infrastructure and property.

The sea levels under the various scenarios were determined and mapped onto existing mapping to establish the level of ingress into what is currently dry land. The inundation maps were used to visually illustrate the sea level rise impacts on the four major Namibian coastal towns (Hentiesbay, Swakopmund, Walvis Bay and Lüderitz) that were certain to be influenced by such changes. Oranjemund would most likely not be impacted by sea level rise. It was determined that Hentiesbay, Swakopmund and especially Lüderitz would only suffer relatively minor impacts. Walvis Bay, however, due to its extremely low elevation is at high risk, compounded by the fact that it is one of Namibia's largest towns having the largest sea port and contributes significantly to the national economy and GDP.

Infrastructure damage was considered on a present value basis (to allow for comparison) based on historic levels of development and relatively simplified projections. It was assumed for all cases that the business-as-usual model of economic and social growth would be followed. Damage was measured in terms of monetary impact, specifically on properties (residential / commercial / industrial), roads, water, sewerage and electrical services.

Water was identified as a key concern for all human settlements along the Namibian coast due to dependence on underground aquifers (which are already under threat at current sea levels and need to be continuously managed). Maintaining current supply would be viable; however, there would be

restrictions that would likely dampen growth. Desalination is already considered a viable option for fresh water supply, especially for the uranium mining industries in the Erongo Region. Siting of future supply points would be an important factor.

It was determined that in the **near future**, most of the coastal towns would likely be able to effectively deal with the impacts of severe weather conditions without having to resort to extreme measures and that costs would be moderate, compared to the local economies. It is clear, though, that a great amount of planning is needed for **long term** adaptation strategies, especially at Walvis Bay, to ensure that current and future infrastructure at this bustling port is safeguarded for continued economic activity.

1.4. **Environmental Impacts and Governance (by Lucinda Fairhurst, LaquaR Consultants)**

The coastline of Namibia stretches for 1500km and is vulnerable to the effects of sea level rise, through processes such as coastline erosion, flooding and saltwater intrusion. These processes could have severe impacts on the natural ecosystems of the coast (fauna and flora), and thus impinge their ability to provide ecosystem services such as: provision of food (fishing), recreation, atmospheric carbon sinks, flood attenuation, replenishment of groundwater, filtering of run-off and air pollution, oxygen production and tourism attraction.

Although coastal erosion is likely to impact on Swakopmund and Walvis Bay in different ways due to their location and topography (Swakopmund is on relatively high ground), the stresses on ecosystem services induced by sea level rise will undermine the resilience of socio-economic sectors that are dependent on those.

A rise in mean sea level rise is projected to slowly inundate wetlands and lowlands resulting in an increase in salinity of estuaries and aquifers. This is projected to be detrimental for coastal areas as they provide spawning and nursery grounds for many fish species. Increased salinity in these areas is likely to lead to the decimation of organisms that are not resistant to the high saline environment. This in turn could affect shore birds that rely on these organisms for foraging habitat during their migration and nesting sites, notably in the wetland at mouth of the Omaruru River in Henties Bay.

Sea level rise will also lead to raised water tables, which could allow an encroachment of polluted water into wastewater treatment, and thus increase the probability of sewage overflow, with the associated human and ecological health hazards. Increased groundwater levels are likely to enhance the vulnerability of communities that are located in low-lying areas, especially when rain and sea storm water is no longer be able to dissipate, thus exacerbating flooding impacts. Much of the town of Walvis Bay lies beneath two metres elevation, which places it under threat from the immediate impacts of sea level rise.

Due to the inherent uncertainty of future climate change impacts, climate change adaptation should be understood as a process. Adaptation strategies which are dynamic and have an increased range of coping responses in order to deal with climate variability are best managed according to the principles of Integrated Coastal Zone Management (ICZM). ICZM aims to reconcile the economic, social, recreational and cultural objectives of the coastal zone, within the limits set by the carrying capacity of the coast. Nonetheless, the existing governance system in Namibia exerts several barriers to the effective implementation of ICZM. This report proposes several tailored strategies to improve Namibia's governance system. These measures aim to improve the content of legislation

and policies (and their enactment, implementation, monitoring and enforcement); to strengthen the institutional framework, and increase horizontal and vertical integration; and finally aim to increase public participation and build capacity.

1.5. **Adaptation Strategies (by Anton Cartwright, Laquar Consultants)**

International climate change efforts were initially focussed on reducing the emission of greenhouse gases. Subsequent acknowledgement that some climate change impacts are already being felt and that atmospheric concentrations of greenhouse gases already commit the planet to more than 2°C of warming¹ has seen a growing recognition of the need to develop climate change adaptation measures. The IPCC's most recent acknowledgement² is that it is now neither possible to mitigate nor adapt sufficiently to avoid severe climate change related impacts and costs.

The oceans absorb more than 80% of the solar irradiation received by the earth and continued warming and expansion over the next century is now unavoidable. Climate change induced sea-level rise, in the form of higher mean sea levels and more intense and frequent sea-storm surges coinciding with high tides, is expected to impose novel costs on the Namibian coastal economy. This study has identified the potential for specific damage to infrastructure, property, threats to communities and disruptions to ecological balances. The extent of this damage can be significantly reduced by preparedness, developing adaptive capacity and pre-emptive actions. Given that these adaptation actions involve costs of their own, the difficulty is in knowing what to do where and when.

The full set of risks associated with sea-level rise in Namibia are complex but include (1) the direct threat of damage to infrastructure, property, human life and the environment, (2) the risk of negative implications that result, including foregone tourism revenue, disrupted economic mobility and the opportunity cost associated with the need to reallocate resources to disaster relief and reconstruction efforts and (3) the risk of piecemeal or uninformed responses to sea-level rise that make things worse by amplifying the problem, inducing unforeseen consequences, or transferring the risk to people who are less able to deal with it.


It is not possible to predict the exact nature and timing of sea-level rise events long in advance (although the accuracy of 5 days forecasts is improving rapidly and combined with tides tables can provide short-term warning), or to provide definitive protection against the wide range of impacts that sea-level rise events can induce. In the context of this uncertainty, adaptation responses that retain options, and promote continued monitoring and flexibility are most valuable. From a financial perspective sea-level rise adaptation options in Namibia can be divided into (1) no regrets options – that are desirable, low cost, high benefit and should be pursued even if climate change was not a threat, (2) sea-level rise specific responses that save more money than they cost and (3) sea-level rise specific options that are necessary (to save human life or heritage value) but are costly. From a methodological perspective, adaptation options can be divided into (1) infrastructure and hard engineering responses (such as sea-walls, dolosses and raising the level of harbours), (2) soft and biological responses such as the retention of wetlands and riparian vegetation in estuaries, beach

¹ Robert Watson, former head of the IPCC, presentation at the ECA conference in Zurich July 2009.

² As articulated by Martin Parry, co-chair of IPCC WG 2, at the ECA conference in Zurich July 2009.

and sandpit replenishment, the planting of dune vegetation to ensure dune buffers are retained and the cultivating of kelp beds that dissipate wave energy and (3) socio-institutional responses such as enforced coastal buffer zones, early warning, insurance market and planned relocations.

Effective decisions regarding which type of option to apply when and where provide the essence of climate change adaptation. Typically the costs per unit benefit and the extent to which options reduce risks constitute the defining selection criteria, but these can be difficult parameters to define accurately, particularly when expanded temporal and spatial scales are considered, the risk of mal-adaptation and the value of ecosystem goods and services is acknowledged. Rather than precise values, a decision process that gives consideration to these criteria is important. When applied, this process tends to reveal that socio-institutional responses should be considered before biological and soft engineering solutions, which should be considered before hard engineering solutions. Similarly, no-regrets options should be prioritised before financially rational and costly but necessary options. Selecting and applying these options is not effective when undertaken in an ad-hoc and reactive manner, but is most effective when part of an integrated coastal resource management strategy that takes cognisance of Namibia's existing development priorities and programmes.



	Costly but necessary	Financially rational	No regrets
Socio-institutional responses	Public insurance or bail-outs. Planned relocation of industry and communities.	Early warning system, informed private insurance	Coastal buffer zones, vulnerability mapping
Biological and soft-engineering responses	Beach drainage	Beach and sandspit replenishment. Dune vegetation programmes	Retaining wetland vegetation, kelp bed management
Infrastructure responses	Sea-walls, barrages, raising the harbour at Walvisbay,	Off-shore reefs, dolosse	

Table 1: Decision support matrix for adapting to Namibian sea-level rise

1.6. Presentations to Stakeholder

A workshop was conducted on 24 July 2009 in Walvis Bay to present the findings of the study to stakeholders. The workshop was attended by a variety of stakeholders from national government, local governments and private companies. After the findings of the study were presented, stakeholders were asked for their input regarding adaptation strategies. Several recommendations were made and were consistent with the recommendations made in Section 8 of this report. The following are few of the recommendations made:

- The findings of this study should be distributed to planners, property developers, public decision-makers, insurance companies, coastal businesses, not-for-profit organisations and residents.
- The predictions for sea level rise should be incorporated onto town planning and zoning maps, and should be considered within environmental impact assessments and strategic environmental assessments that are prepared for future / potential coastal development projects.
- The types of sea level data recorded by the Ministry of Fisheries, NamPorts and other institutions should be standardised. Furthermore, consideration should be given to establishing a national office that is responsible for collecting, storing and distributing data and information related to sea level rise.
- Sea level rise should be factored into a White Paper on Coastal Zone Management.
- Environmental legislation needs to be advanced as part of an adaptation strategy to increase the resilience of ecosystems to the impacts of sea level rise.

The report findings were also presented to the Erongo Regional Council during a Council meeting on 4 September 2009. While no specific recommendations were made by the Regional Council, the issues of climate change and sea level rise were recognised as important ones.

Table of Contents

1. EXECUTIVE SUMMARY.....	2
1.1. Introduction.....	2
1.2. Sea Level Rise Assessment (<i>by Professor Geoff Bundrit, LaquaR Consultants</i>).....	2
1.3. Impacts on Property, Infrastructure and Water Resources (<i>by Danie Nel, Lithon Project Consultants</i>).....	4
1.4. Environmental Impacts and Governance (<i>by Lucinda Fairhurst, LaquaR Consultants</i>).....	5
1.5. Adaptation Strategies (<i>by Anton Cartwright, LaquaR Consultants</i>).....	6
1.6. Presentations to Stakeholder.....	7
TABLE OF CONTENTS.....	10
TABLE OF FIGURES.....	13
TABLE OF TABLES.....	13
ABBREVIATIONS.....	14
2. INTRODUCTION.....	15
3. BACKGROUND INFORMATION COLLECTION AND PROCESSING.....	16
3.1. Background.....	16
3.2. Collection of mapping information.....	16
3.3. Collection of social and economic, demographic information.....	16
3.4. Collection of water information.....	16
4. SEA LEVEL RISE ASSESSMENT FOR THE COAST OF NAMIBIA.....	17
4.1. The approach.....	17
4.2. The first study: Extreme sea levels along the coastline of Namibia.....	17
4.2.1. The Tides.....	18
4.2.2. The Weather Effect.....	19
4.2.3. Sea Level.....	19
4.2.4. The Kwa Zulu Natal Storm of March 2007.....	20
4.2.5. Wave Run-up and Storm Impact.....	21
4.2.6. Potential Damage from Coastal Erosion.....	23
4.2.7. Scenario One: The Present Day Worst Case Scenario for the Coastline of Namibia.....	23
4.3. Second study: Sea level rise projections in the near future along the coastline of Namibia.....	25
4.3.1. Scenario Two: The Sea Level Scenario at 2030.....	28
4.4. Third study: Sea level rise scenarios along the coastline of Namibia after collapse of the polar ice sheets.....	29
4.4.1. Scenario A.....	30

4.4.2.	Scenario B.....	30
4.4.3.	Scenario C.....	30
4.4.4.	Scenario Three: The Polar Ice Sheet Melt Scenario	31
4.5.	Fourth study: Sea level rise impacts along the coast of Namibia, with an emphasis on Walvisbay.....	31
4.5.1.	Impact on Walvisbay as a Sheltered Coastal Environment	34
4.5.2.	Impact on Walvisbay as an Exposed Coastal Environment	36
4.5.3.	Consequences of the Polar Ice Melt Scenario	39
5.	ANALYSIS OF IMPACTS	40
5.1.	Methodology	40
5.2.	Global environmental analysis.....	41
5.3.	Map analysis	42
5.4.	Socio-economic background study	43
5.5.	Assumptions.....	48
5.6.	Study 1: Year 2009 extreme sea levels	50
5.7.	Study 2: Sea level rise projected for the near future (2030).....	53
5.8.	Future scenarios under significant atmospheric GHG concentration increases	56
5.9.	Study 3(a): Sea level rise scenario	57
5.10.	Study 3(b): Sea level rise scenario	60
5.11.	Study 3(c): Sea level rise scenario after collapse of polar ice caps.....	64
5.12.	Study 4: Other impacts of sea level rise and notes.....	67
5.13.	Conclusions.....	72
6.	ENVIRONMENTAL ANALYSIS.....	75
6.1.	Introduction.....	75
6.2.	Sea Level Rise and the Namibian Coastal Ecosystems.....	77
6.3.	Impacts associated with Sea-level Rise:	79
6.4.	The governance system of Namibia’s coastal areas.....	89
6.5.	Barriers to ICZM.....	92
6.6.	Issues of Best Practice.....	98
6.7.	Conclusion	102
7.	ADAPTATION STRATEGY OPTIONS.....	103
7.1.	Introduction.....	103
7.2.	Climate change adaptation	104
7.3.	Adapting to sea-level rise.....	105
7.4.	Options for Namibia.....	106
7.5.	Institutional responses.....	114

7.6. Selecting the most appropriate adaptation measure	118
8. ANNEX I – SOURCES AND PROCEDURES	123
8.1. Citations and other sources of background information and statistics:.....	123
8.2. Entities contacted to obtain town planning (cadastral and land use):	128
8.3. Entities contacted to obtain infrastructure planning (bulk municipal service):.....	128
8.4. Entities contacted to obtain contour mapping:.....	128
8.5. Entities contacted to obtain environmental mapping:	129
9. ANNEX II – INUNDATION MAPPING	130
9.1. Walvisbay.....	130
9.2. Swakopmund.....	135
9.3. Lüderitz	137
9.4. Hentiesbay.....	138
9.5. Long Beach and Dolphin Beach	140
9.6. Interurban areas.....	141
10. ANNEX III – CALCULATIONS.....	145
11. ANNEX IV – STAKEHOLDER WORKSHOP, 24 JULY 2009	154
11.1. List of invitees.....	154
11.2. Attendance register	159
11.3. Presentations	160
11.4. Recommendations.....	176

Table of Figures

Figure 1: Present Day Port Diagram for Walvisbay.....	20
Figure 2: Present Day Port Diagram for Luderitz	20
Figure 3: Coastal damage from the March 2006 storm on the KwaZulu Natal, South Africa coast.....	22
Figure 4: Coastal damage from the March 2006 storm on the KwaZulu Natal, South Africa coast.....	22
Figure 5: Offshore wave-riders at Walvisbay (left) and at Luderitz (right)	24
Figure 6: Monthly mean sea level at Walvisbay	26
Figure 7: Monthly mean sea level at Luderitz.....	26
Figure 8: Monthly mean sea level at Port Nolloth, South Africa	26
Figure 9: Annual mean sea level at Luderitz.....	26
Figure 10: Annual mean sea level at Port Nolloth	26
Figure 11: Port Diagram at Walvisbay, present day and projected to 2030.....	28
Figure 12: Port Diagram at Luderitz, present day and projected to 2030	28
Figure 13: Oranjemund on Google Earth	32
Figure 14: Luderitz on Google Earth.....	32
Figure 15: Swakopmund on Google Earth	33
Figure 16: Walvisbay on Google Earth.....	33
Figure 17: Port Diagram for Walvisbay, at Present and Projected for the Year 2030	34
Figure 18: The location of Walvisbay (from Hughes et al 1992).....	36
Figure 19: Sandwich Harbour on Google Earth	37
Figure 20: Baia dos Tigres, southern Angola on Google Earth.....	37
Figure 21: Walvisbay after 1m sea level rise, from www.flood.firetree.net	38
Figure 22: Uncertainty and risk increase with added layers of complexity	43
Figure 23: Image of Welwitschia mirabilis, an ecologically highly specialized endemic plant that grows in isolated communities in the Namib Desert.....	81
Figure 24: The Damara Tern	83
Figure 27: An example of a modern seawall on the Isle of Wight, UK	110
Figure 28: Concrete blocks used off the coast of Australia to create an artificial reef. The rocks have been designed to create refuge for sea-life.....	111
Figure 29: Established mangrove plantations on the coast of Fiji seek to restore degraded vegetation and coastal buffers against sea-level rise and storm surges.....	113

Table of Tables

Table 1: Decision support matrix for adapting to Namibian sea-level rise	7
Table 2: Deep Water Significant Wave Heights along the Coast of Namibia.....	24
Table 3: Accumulated sea level rise to 2030.....	27
Table 4: Deep Water Significant Wave Heights for offshore of Walvisbay.	38
Table 5: relative cost, benefits, potential for unforeseen consequences and suitability of the adaptation options	122

Abbreviations

CSA	- Consulting Services Africa
EIA	- Environmental Impact Assessment
EPZ	- Export Processing Zone
GDP	- Gross Domestic Product
GHG	- Greenhouse Gas
GNI	- Gross National Income
IPCC	- Intergovernmental Panel on Climate Change
LAB	- Local Action for Biodiversity
LIDAR	- Light Detection and Ranging
LLD	- Land Levelling Datum
MET	- Ministry of Environment and Tourism
ppm	- Parts per million
UDA	- Urban Dynamics Africa
UNFCCC	- United Nations Framework Convention on Climate Change
WWF	- World Wildlife Fund

2. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992 as a global response to the threat of global warming. Namibia ratified the UNFCCC in 1995 as a Non-Annex I Party. As such Namibia agreed to establish national programmes to slow climate change and to consider climate change within its development plans and activities for agriculture, energy, industry, natural resources, and the sea coast. The UNFCCC further recognises the vulnerability of developing countries such as Namibia to climate change, and it calls for efforts to assist developing countries to adapt to the expected impacts of climate change such as sea level rise.

This study was commissioned by the Ministry of Environment and Tourism (MET) for multiple reasons. First, Namibia will soon prepare its Second National Communication (SNC) to the UNFCCC; the findings and recommendations of this study will be incorporated into the SNC. Second, while Namibian stakeholders have been aware of global predictions for sea level rise, it is important that they are informed about the specific changes in sea level and storm surges that could be expected along Namibia's coast; this study addresses Namibia-specific conditions and scenarios. Third, it is important that Namibian stakeholders are informed about the possible impacts to Namibian property, infrastructure, water resources and ecosystems, and the options and recommended strategies for Namibia to adapt to those impacts; this study also addresses those needs. Finally, in addition to above reasons for commissioning this study, it is also envisaged that the MET would be able to use this study as a basis to apply to the Global Environment Facility for funding to support future programmes in Namibia to adapt to sea level rise and climate change.

The study includes four major sections. The first section (Section 4) is an assessment of the potential future changes in sea level rise along Namibia's coastline. The assessment considers several different scenarios and identifies the relative level of exposure of different coastal towns to sea level rise and storm surges. The second section (Section 5) is an analysis of the potential impacts to property, infrastructure and water resources. The second section includes a set of maps that indicate the areas within coastal towns that could potentially be impacted. The third section (Section 6) focuses on potential impacts to the Namibia's coastal wetlands and ecosystems. The third section also discusses issues of governance that are related to sea level rise. The fourth section (Section 7) is a comprehensive discussion of options and strategies to adapt to sea level rise.

3. Background information collection and processing

Information gathering and preparation

3.1. Background

Initially gathering the relevant mapping data for coastal towns and environmentally sensitive areas was the priority of this study. The aim was to integrate the various information items into a coherent framework, to present to stakeholders for their interaction. Mapping was considered to be vital in this regard.

3.2. Collection of mapping information

Town (cadastral and municipal services) and environmental mapping were combined with contour plans to determine the extent of impacts of sea level changes. A list of relevant sources contacted to obtain this information is provided in Annex I.

3.3. Collection of social and economic, demographic information

Demographic and social information was limited to local town planning, since most of the settlement occurred around the major town centres and the indigenous peoples live mostly inland – removed from the immediate impacts of sea level rise.

Economic and demographic data was gathered from various sources and censuses.

Tourism background information was obtained from various resources. It was assumed for a large part that the tourism industry along the coast would be directly impacted by a few key factors: accessibility to areas of interest (dependant on infrastructure), the environment itself (often the actual areas of interest), perceived risk (likelihood of storms and their impacts) and the availability of amenities (tourist facilities such as accommodation and supporting industries).

Sources of this report are disclosed in Annex I.

3.4. Collection of water information

Data was gathered from internal data sources and from the Namibia Water Corporation (Namwater), through Mr. Wynand Seimons.

4. Sea level rise assessment for the coast of Namibia

By Dr. Geoff Brundritt (Laquar Consultants, March 2009)

Investigation and categorisation of possible sea level rise scenarios and impacts

4.1. The approach

In order to achieve the assessment, the following approach was taken:

- Review the nature of extreme sea level events along the coastline of Namibia, so as to establish the various contributions/components/constituents that might evolve under the effects of climate change. This will be achieved through a re-interpretation of sea level records from the SA Navy Tidal Network stations at Walvisbay and Luderitz. This forms the **First Study**, which provides a **Present Day Worst Case Scenario** of extreme sea levels for use in the GIS Inundation Model for the coastline of Namibia.
- Review global projections of the influence of climate change on sea level, as given in studies such as the recent Assessment Reports of the Inter-Governmental Panel on Climate Change. This will provide estimates of the influence of climate change on local constituents of sea level in the vertical, as a series of projections on decadal and centennial scales, together with their range of uncertainties. The Second Study gives estimates of sea level rise for the coastline of Namibia in the near future, and provides the Scenario at the Year 2030. The Third Study focuses on the much more uncertain longer term situation when wholesale ice melting is expected to lead to greatly enhanced sea level rise, and provides the Polar Ice Sheet Melt Scenario and its effects on the coastline of Namibia on century time scales.
- Build these projections of sea level rise into assessments of impacts on the coast of Namibia, noting especially vulnerable locations and infrastructure and activities at risk. This constitutes the Fourth Study. The threat of sea level rise to the urban area of Walvisbay, with its major harbour, receives particular attention.

4.2. The first study: Extreme sea levels along the coastline of Namibia

There is concern about the impact of extreme sea levels on infrastructure and services along the coastline of Namibia, especially with the threats of sea level rise and increased storminess associated with global warming. The purpose of this first study is to summarise what is known about present day sea levels, with an emphasis on extreme events and on particularly vulnerable sections of the coastline. Once this study is complete, it will be possible to shift the focus onto the implications of the future addition of sea level rise to the situation.

There are essentially three factors that contribute to present day sea level: tides, weather effects and wave set-up, though the last mentioned only affects surf zones. They have different characteristics, so the three factors need to be carefully combined to assess their total contribution and potential impact. The material relevant to the coastline of Namibia is extracted and embellished in this study.

4.2.1. The Tides

The tides are completely predictable and affect the entire coastline in a uniform way. However, tidal heights vary on a daily, fortnightly, seasonal and on a year to year basis. The detail is provided in the *Tide Tables* published on an annual basis by the Hydrographic Office of the South African Navy, and the information for Luderitz and Walvisbay is particularly relevant to this study.

In this study, the Land Leveling Datum (LLD), rather than Chart Datum (CD), is used as a baseline for all heights and levels. LLD is derived from the terrestrial geodetic network used for land in Namibia, which approximates to mean sea level at the coast. The relationship between LLD and CD over the years is tabulated in the Tide Tables.

Tidal Characteristics	Walvisbay	Luderitz
Mean Tide Level (MTL)	LLD	LLD-13cm
Mean High Water Neaps (MHWN)	LLD+31cm	LLD+16cm
Mean High Water Springs (MHWS)	LLD+71cm	LLD+54cm
Highest Astronomical Tide (HAT)	LLD+102cm	LLD+89cm

The sea is depressed at Luderitz, and along probably the coast of southern Namibia, from the effect of the strong prevailing winds. The relative tidal heights are comparable and can be used as representative of the entire coast of Namibia.

Within each fortnight between full moon and new moon, high tide over the days of neap tide typically only reaches levels of 31cm above LLD at Walvisbay and 16cm above LLD at Luderitz whilst, over the days of spring tides, the high tide reaches 71cm above LLD at Walvisbay and 54cm above LLD at Luderitz. The overall maximum spring high tide is much higher, being the Highest Astronomical Tide at LLD+102cm at Walvisbay and LLD+89cm at Luderitz. The tide does not reach HAT every year. HAT is the maximum tidal height reached in the 18.6 year cycle of the precession of the Moon's ascending node (also known as the Saros cycle). The mean for the other tidal measures is also taken over this long 18.6 year cycle time.

When it comes to extreme tides, only high water at spring tides occurring around the time of full and new moon, rather than at neap tides, need to be taken into account. These spring high tides exhibit great variability in height, but have a regular pattern (the equinoctial, lunar perigee and Saros cycles) over the long term. In any given year, the spring high tides peak in the seasons of spring and autumn as part of the equinoctial cycle, so that the Highest Astronomical Tide of the Year (HATOY) will occur in one of the months within spring or autumn. HATOY will also be higher in those years when the Moon's perigee occurs in spring or autumn, which happens every 4.4 years. HATOY has a range of some 12cm along the coast of Namibia, reaching HAT in the peak year of the Saros cycle. The next year when HATOY is close to peak is the year 2011.

The highest tides are restricted to a few hours on particular days in particular months in particular years and are completely predictable. If the tides are the determining factor in

extreme sea level (*Searson and Brundrit 1995*), and this is the case in Namibia, it will be important to note these times of particular vulnerability. The dates and times and heights can be extracted from the Tide Tables, which are published each year by the Hydrographer of the South African Navy.

4.2.2. **The Weather Effect**

The effect of passing synoptic weather systems means that observed sea level can be higher than the predicted tide when the air pressure is low and when the wind piles the water up against the coast (passing mid-latitude depressions; low pressure systems; cold fronts). As with the tides, the entire coastline is affected. Synoptic weather effects last for two or three days, but their predictability is limited to little more than one week. Forecasts of severe weather are issued by the South African Weather Service.

While individual depressions do vary in their intensity and duration, their statistical characteristics vary little from year to year. An overall description can be obtained from the nine year record of hourly observations of sea level from Walvisbay and the ten year record from Luderitz between 1981 and 1990 (*Searson and Brundrit 1995*). The almost 70,000 hourly deviations of sea level from the predicted tide at Walvisbay and the almost 85,000 hourly deviations at Luderitz, due to the synoptic weather effect, form an essentially normal distribution with standard deviations of 8.64cm at Walvisbay and 7.52cm at Luderitz.

For further study of the extreme values, the deviations can be grouped into monthly maxima for each month of the record from each station. The overall monthly maximum deviation at Walvisbay was + 20cm, whilst in 12 of the monthly maxima, the deviation exceeded +10cm. The overall monthly maximum deviation at Luderitz was + 25cm, whilst in 17 of the monthly maxima, the deviation exceeded +10cm. The spread of these extreme monthly maximum deviations was not uniform over the year. At both ports, the first quarter of the year showed the biggest deviations with February tending to show the maximum deviation with an average deviation of 15cm.

4.2.3. **Sea Level**

The records of observations of sea level can be analysed for extremes of the joint effect of tides and weather on sea level around the coast of Namibia. Such an analysis gives the mean sea level observed at Walvisbay as LLD+3cm, with an overall maximum sea level of LLD+116cm, and the mean sea level at Luderitz as LLD-12cm, with an overall maximum sea level of LLD+93cm. The highest observed sea levels at Walvisbay and Luderitz in these observational records all coincided with near equinoctial spring high tides, emphasizing the dominance of the tide over the weather and the enhanced vulnerability at the time of such events. Although these maximum sea levels at both ports exceed their respective HATs, they do not reach the level of $(LLD+102) + 20\text{cm} = LLD+122\text{cm}$ at Walvisbay, or $(LLD+89) + 25\text{cm} = LLD+114\text{cm}$ at Luderitz, which would be achieved on the simultaneous occurrence of HAT (an 18.6 year tide event) and a 10 year storm event. Such a joint extreme event has a return period approaching 200 years.

Port Diagrams showing the detailed return periods for extreme sea levels to be expected at Walvisbay and at Luderitz are provided in *Searson and Brundrit 1995*, whilst simplified Port Diagrams, based on annual maxima, are shown here.

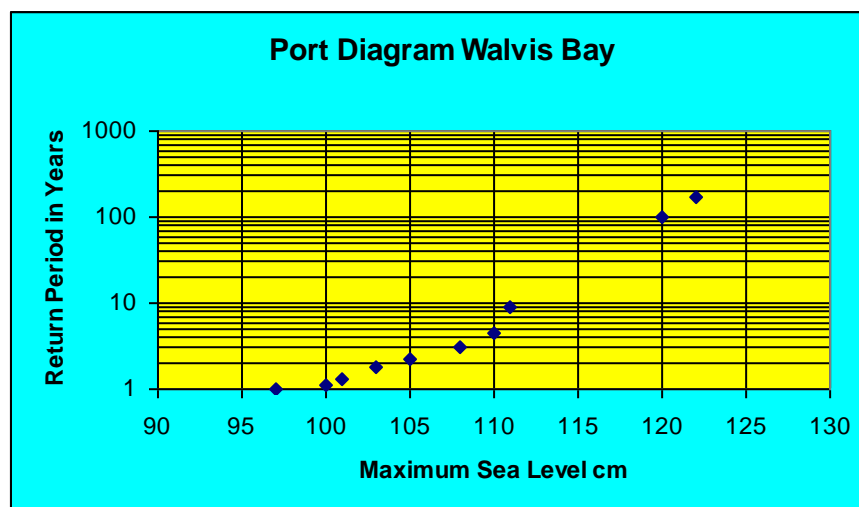


Figure 1: Present Day Port Diagram for Walvisbay

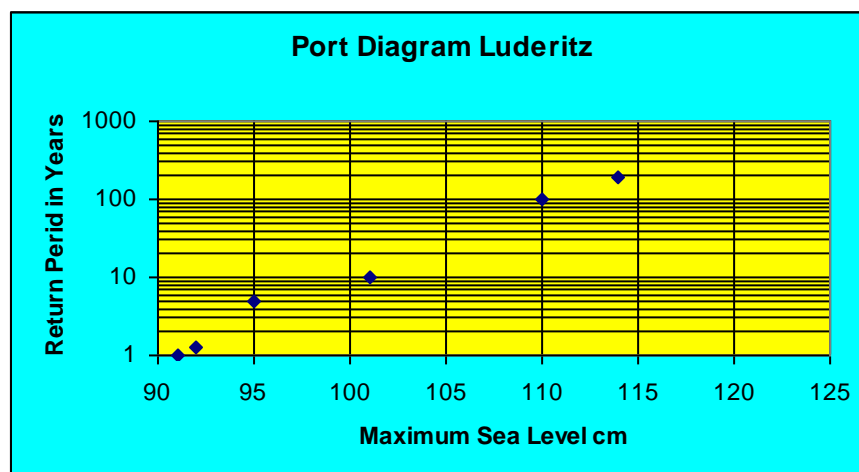


Figure 2: Present Day Port Diagram for Luderitz

The nine years of observed annual maximum sea levels are used in the Port Diagram for Walvisbay and ten years for Luderitz. Extrapolation of maximum sea levels for the longer return period of 100 years is shown for illustration. These extrapolations are consistent with the joint extreme event of a Saros spring tide and observed maximum weather effect of LLD+122cm at Walvisbay and LLD+114cm at Luderitz.

4.2.4. The Kwa Zulu Natal Storm of March 2007

The simultaneous occurrence of a tidal height close to HAT and an estimated 30 year storm occurred along the coast of Kwa Zulu Natal (KZN) in the early hours of 19 March 2007 (*Smith, Guastella, Bundy and Mather 2007*). The measurements taken at that time provide a valuable resource for confirming the approach taken for the coast of Namibia, and for suggesting values that should be used on exposed coasts.

The Highest Astronomical Tide for Durban is LLD+139cm. A ten year record of sea level observations from Durban from 1980-1990 again shows the deviation of observed sea level from the predicted tide to be normally distributed, with a standard deviation of 10.3cm (*Searson and Brundrit 1995*). The maximum deviation over the ten years gives an extra height of +37cm. The simultaneous occurrence of HAT and a ten year storm leads to a sea level of LLD+176cm with a return period of some 180 years. By contrast, the earlier ten year record of sea level observations gives a maximum sea level of LLD+159cm.

Turning to the situation on the KZN coast early on the morning of 19 March 2007, the observed sea level was LLD+188cm. The predicted early morning high tide for 19 March was only LLD+133cm, giving a contribution from the storm of +55cm. Such an extreme storm probably has a return period approaching 100 years, while the joint event of high spring tide and severe storm will have a return period of 500 years.

4.2.5. **Wave Run-up and Storm Impact**

The effect of wave run-up can now be summarized. This occurs due to interactions in the surf zone, where there is an increase in the water level leading to more vigorous run-up in the swash and intensified erosion of dune faces and other soft material. Measurements were made during the storm on the KZN coast in the early morning of 19 March 2007, and are reported in *Smith, Guastella, Bundy and Mather (2007)*. Referring these measurements to Land Levelling Datum rather than Chart Datum, the landward edge of the swash zone was surveyed at LLD+700cm in the Durban area, whilst at Ballito and Salt Rock the same swash levels were recorded at locations with a southerly aspect, adjacent to headlands. The erosion line for this storm was consistently located between the 4 and 5m contours above mean sea level, with the high water mark retreating by between 10-30m in a few hours as the nearshore sand was rapidly washed away. These extraordinary levels are consistent with the extreme intensity of the storm and the dramatic damage along the coast. "Roads were damaged at Margate, Uvongo, St Michael's-on-Sea, Port Shepstone, Umkomaas, Durban, Umdloti, Ballito and Zinkwazi. The South Coast railway-line experienced severe damage at Mtwalume and Sezela. Private property along the coast was also damaged. The provisional repair bill exceeds one billion rand. (*Smith, Guastella, Bundy and Mather 2007*)".



Figure 3: Coastal damage from the March 2006 storm on the KwaZulu Natal, South Africa coast



Figure 4: Coastal damage from the March 2006 storm on the KwaZulu Natal, South Africa coast

4.2.6. **Potential Damage from Coastal Erosion**

Coastal type and exposure influenced the severity of damage along the KZN coast. Sandy and rocky coastal sections generally withstood the storm's onslaught, but mixed coastlines of rock and sand, especially pocket beaches, were severely impacted. It was also noted that this severe storm came after a rather stormy season, which may have weakened the natural defences of the sandy coast. Many built structures that failed were located adjacent to, or upon, rocky headlands, and within bays encompassed by rock shelves. Wave energy was focused in these areas, especially where over-wash was not allowed to dissipate naturally.

There are lessons for the identification of areas along the coastline of Namibia which are vulnerable to the impacts from severe storms. The coastline of Namibia is some 1500km long, with 78% consisting of sandy beaches, 16% rocky shores, 4% mixed and 2% backed by lagoons, *UNFCCC (2002)*. These percentages emphasise the dominance of dynamic sandy beaches, characterized by both wind-blown sand and wave-driven longshore sediment transport in the sea. These areas are recognized as being unsuitable for infrastructure development, which then tend to be set back from the coast and are protected from the sea by the coastal dune fields.

Dunes must be high enough and wide enough to afford protection from the sea. Particular care must be taken to assess the ability of the dune cordon to stand firm against repeated attacks from the sea. Once breached, infrastructure and services on land beyond the dunes is exposed to the risk of direct attack from the sea. A careful investigation of the land behind the sandy coastal spits protecting Walvisbay and Luderitz is indicated. It should not be forgotten that Namibia is subject to high waves from extra-tropical depressions passing to the south of the continent, as well as cut-off lows similar to the one that affected the coast of KwaZulu Natal.

4.2.7. **Scenario One: The Present Day Worst Case Scenario for the Coastline of Namibia**

This Scenario is taken to result from the simultaneous occurrence of an extreme tide and an extreme storm, an event with a nominal return period of 100 years. The example of a 100 year severe storm coinciding with an equinoctial spring high tide can be used for illustration. Such an event has not occurred along the Namibian coast in recent years but an event with a return period estimated at 500 years did occur along the KZN coast on 19/20 March 2007. Measurements taken from the KZN extreme event have been incorporated into this Present Day Worst Case Scenario, particularly in respect of exposed and very exposed portions of the coastline. The erosion damage in KZN was spectacular, and similar damage should be anticipated along vulnerable sections of the Namibian coast in such extreme circumstances. The identification of these vulnerable sections of the coast is an important output from this scenario.

The Scenario distinguishes between sheltered, exposed and very exposed coastal environments. The sea level due to the joint effect of the tide and the weather provides the sea level to be expected in sheltered environments along the coast of Namibia. The values coast are taken directly from the maximum sea level to be expected for a return period of 100 years as given in the Port Diagrams. At Walvisbay, this is estimated at LLD+120cm,

and at Luderitz at LLD+110cm. These will be the values that are appropriate in all sheltered environments along the coast of Namibia, in particular to the areas behind the offshore protective sand spits at Walvisbay and Luderitz where the key observations were originally taken.

In exposed coastal environments, wave set up needs to be added whilst in very exposed environments wave run up also becomes important. For these, the extreme wave climatology of the Namibian coast needs to be examined. Wave recorders have been maintained in deep water offshore of Walvisbay and Luderitz, and deep water significant wave heights can be estimated for various return periods, *Rossouw 1989*.

Return period	1 Year	10 Years	100 Years
Walvisbay	3.6m	4.4m	5.2m
Luderitz	6.3m	7.7m	9.1m

Table 2: Deep Water Significant Wave Heights along the Coast of Namibia.

The deep water wave climate is much more extreme in the vicinity of Luderitz than at Walvisbay, reflecting its more southerly position. For comparison, the deep water wave climate on the Kwa Zulu Natal coast is more extreme than Walvisbay but less extreme than Luderitz.

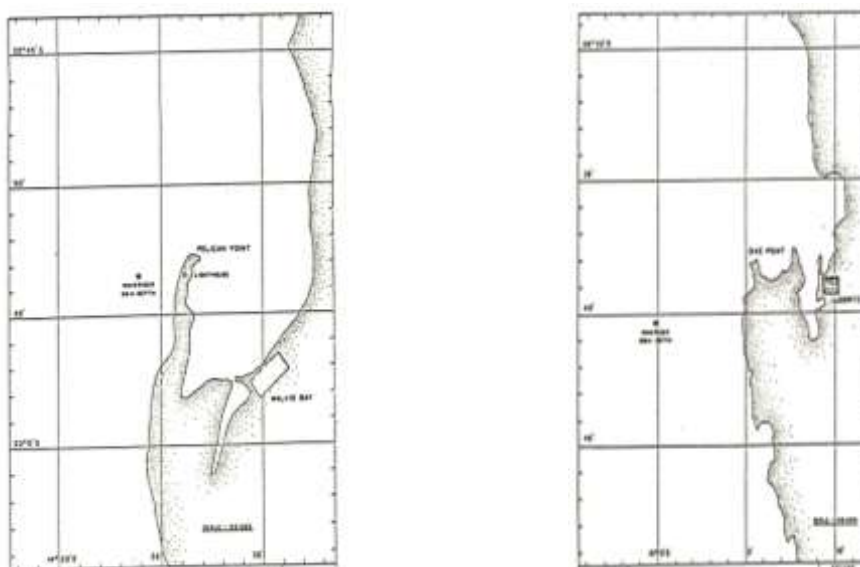


Figure 5: Offshore wave-riders at Walvisbay (left) and at Luderitz (right)

It is now possible to provide values for the maximum sea levels to be expected along the coast of Namibia, in exposed and very exposed environments. For an exposed coast, the values for sheltered environments need to be adjusted upwards for wave set-up, estimated as thirty percent of the deep water significant wave height at the 100 year return period. On an exposed coast on the seaward side of the spit offshore of Walvisbay, this maximum sea level to be expected is estimated at $LLD+120+156\text{cm} = LLD+276\text{cm}$, and near to Luderitz at $LLD+110+273\text{cm} = LLD+383\text{cm}$.

Where deep water is found close to a steeply shelving beach, the coast is very exposed. Wave run up provides a further influence as the waves erode the face of dunes on the beach. The observations from the KZN storm of March 2007 can be used to provide suitable estimates. These suggest that the most extreme storm will reach an erosion line of LLD+400cm to 500cm, and a swash line of LLD+700cm, and will cut back the dune by 20 to 30m during the extreme event. Measurements taken at Oranjemund confirm these suggestions, as wave run-up commonly reaches LLD+410cm and on occasion reaches LLD+470cm (*Theron 2007*). Note that this Present Day Worst Case Scenario has not been experienced along the coast of Namibia).

In summary, and using rounded values derived from sea level and wave observations at Walvisbay and Luderitz, the maximum levels that should be expected to be reached by the sea along the coast of Namibia, in this Present Day Worst Case Scenario are:

LLD+1.5m in sheltered environments LLD+4m in exposed environments, and LLD+6m in very exposed environments
--

The levels expected in northern Namibia can be reduced, because of the less extreme wave climate in exposed and very exposed environments.

Of particular interest will be situations where existing (dune) protection is eroded away in the storm and seawater is able to reach into unprotected areas of low-lying land. Because this scenario is possible (though unlikely) in the present day situation, it deserves to be carefully studied so that the extent of potential economic loss can be assessed.

4.3. **Second study: Sea level rise projections in the near future along the coastline of Namibia**

Observations of sea level globally show a statistically significant sea level rise as part of human-induced climate change. At present, the rate of sea level rise is slow, but it does appear to be accelerating. This second study is intended to describe the situation along the coastline of Namibia, and to extrapolate from this situation so as to provide an estimate of the likely trends in the near future. The potential massive contribution to sea level rise from new climate change processes such as the melting of the polar ice sheets is the subject of the third study.

The primary effects of climate change in the coastal zone are the potential modifications due to sea level rise and storminess. The latest sea level rise predictions and their applicability to southern Africa are reviewed in *Theron 2007*, providing a useful context within which to place this study of sea level rise along the coastline of Namibia. Any analysis of sea level rise requires careful and consistent observations of sea level over several decades. These are not really available in southern Africa (*Brundrit 1995*), nor in Africa as a whole (*Woodworth, Aman and Aarup 2007*).

Records of monthly mean sea level are available for Luderitz and Walvisbay from the Permanent Service for Mean Sea Level (PSMSL), which applies rigorous quality checks on such data. The PSMSL uses RLR sea level rather than LLD as its datum, but any trend in sea level is clear where the data is of sufficiently high quality.

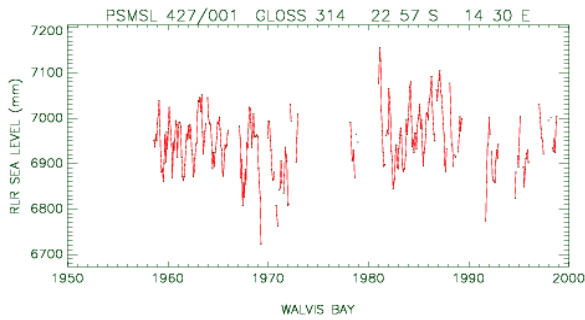


Figure 6: Monthly mean sea level at Walvisbay

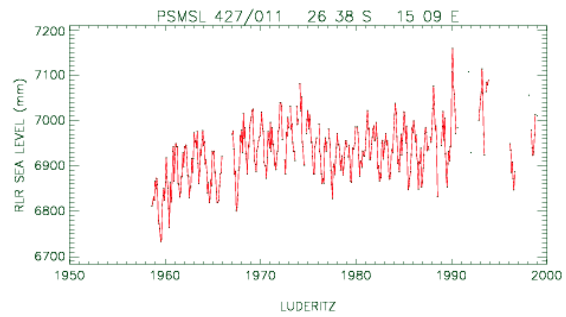


Figure 7: Monthly mean sea level at Luderitz

Compared to Luderitz, the record of monthly mean sea level from Walvisbay shows many gaps and no discernable trend. However, the trend at Luderitz is also present in the sea level record from the nearest South African station at Port Nolloth.

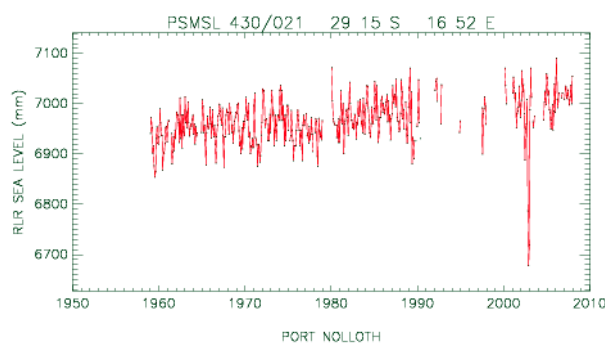


Figure 8: Monthly mean sea level at Port Nolloth, South Africa

These trends can also be seen in the records of annual mean sea level at Luderitz and Port Nolloth.

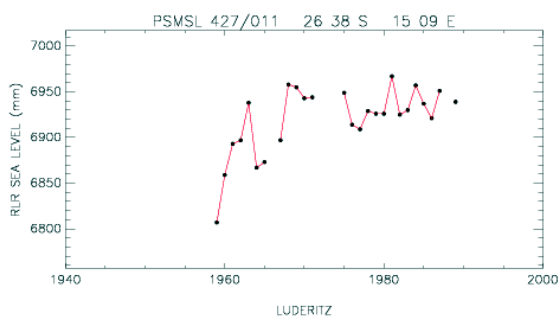


Figure 9: Annual mean sea level at Luderitz

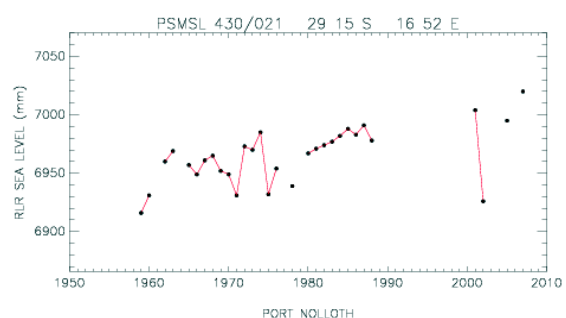


Figure 10: Annual mean sea level at Port Nolloth

Some important conclusions can be drawn from the reliable sections of this data. Annual mean sea level appears to shift between two distinct higher and lower sea level states. Similar shifts between warmer and cooler states are found in annual sea surface temperature observations for the South Atlantic. Both higher and lower states exhibit an upward trend in sea level of approximately 2mm per year, which is consistent with southern African regional records of sea level rise assembled by Church *et al* 2004, and with the accepted global rate of sea level rise over the same period.

The Intergovernmental Panel on Climate Change in its Fourth Assessment Report has provided a Summary for Policy Makers, *IPCC (2007)*. In discussing observed changes in climate and their effects, the IPCC reports as follows. "Rising sea level is consistent with warming. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm per year and since 1993 at

3.1 [2.4 to 3.8] mm per year”, and “Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer term trend is uncertain”.

In its projections of future changes in climate over the 21st century, the IPCC draws on a set of models of sea level rise at 2090-2100 relative to 1980-1999, which exclude rapid dynamical changes in ice flow. This is an important reservation. The recently documented ice melting, both at sea and on the polar ice-caps, has led the IPCC to abandon its earlier projections, including its upper bound. Now in its Synthesis Report, *IPCC AR4(Nov 2007)*, it states that “because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or upper bound for (future) sea level rise”.

It would therefore appear to be prudent to restrict projections of sea level rise based on extrapolations of current trends to the near future. Even there, the extrapolations would cover a wide range, depending on whether sea level rise reverts to its earlier rate, maintains its new rate, or continues to accelerate at a constant rate.

Decade	Revert	Steady	Accelerate
1980-1989	1.8cm	1.8cm	1.8cm
1990-1999	3.1cm	3.1cm	3.1cm
2000-2009	1.8cm	3.1cm	4.4cm
2010-2019	1.8cm	3.1cm	5.7cm
2020-2030	1.8cm	3.1cm	7.0cm
Accumulated	10.3cm	14.2cm	22.0cm

Table 3: Accumulated sea level rise to 2030

At 2030, the sea level is expected to have risen by some 20cm, so that there is little threat of massive new inundation. The levels are not a great change from present day circumstances. For exposed and very exposed coastal environments, the impact will depend on the intensity of the storm and the erosion to be expected along the coast. In the future, storms will cause more damage because climate change is expected to increase the frequency of extreme storms, and, with the danger of dune barriers weakening from a series of extreme storms, the situation could well become even more serious.

What is different is how often any particular sea level can be expected in a sheltered coastal environment. This can be seen by plotting additional points on the earlier Port Diagrams for Walvisbay and Luderitz. As well as maximum sea levels based on the original observed annual maximum sea levels, pertinent to the present day, new points are shown which increase each maximum sea level by 20cm, whilst retaining their appropriate return period. These are the Port Diagrams relevant to the present day and to the year 2030.

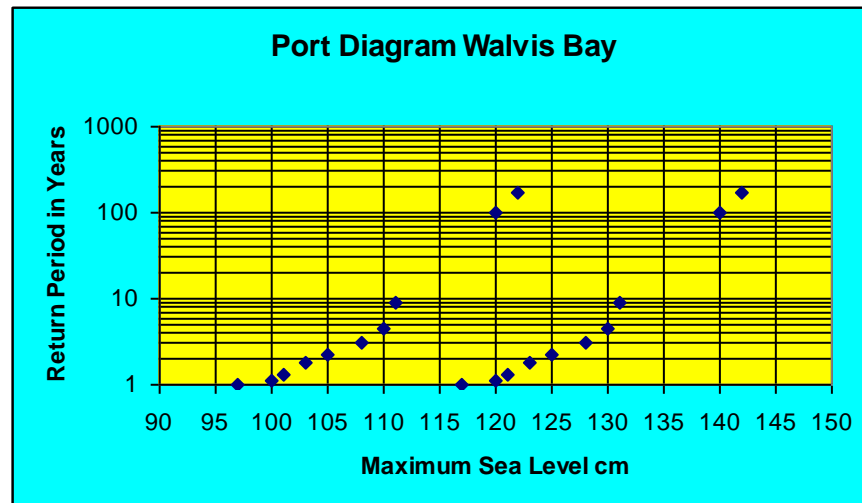


Figure 11: Port Diagram at Walvisbay, present day and projected to 2030

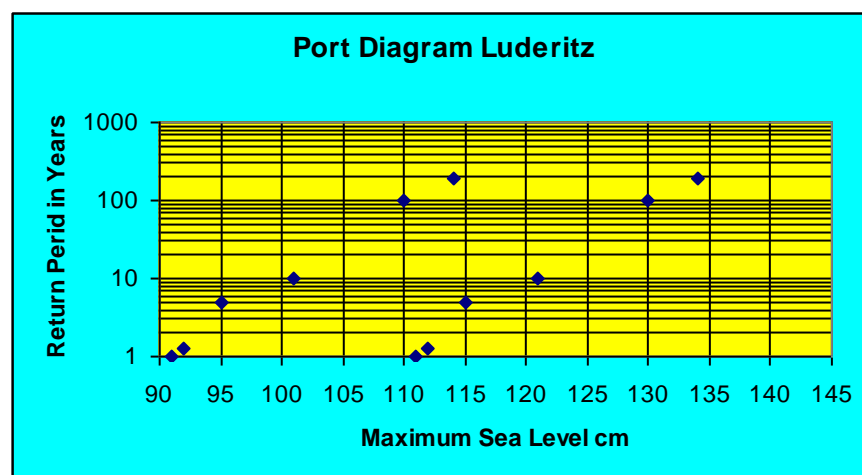


Figure 12: Port Diagram at Luderitz, present day and projected to 2030

At Walvisbay, the present day extreme sea level of LLD+120cm with an expected return period of 100 years should be compared with the sea level of LLD+120cm expected to occur every year in 2030! Similarly, at Luderitz, the present day extreme sea level of LLD+110cm at an expected return period of 100 years should also be compared with the sea level of LLD+111cm expected with a return period of only one year in 2030.

4.3.1. Scenario Two: The Sea Level Scenario at 2030

This is the scenario after the acceleration in sea level rise which is expected to add 20cm to base levels by the year 2030. Given the comparatively small rise in the sea level over this period, the levels to be used in this Scenario Two and the details of the inundation to be expected are the same as in Scenario One!

LLD+1.5m in sheltered environments,
LLD+4m in exposed environments, and
LLD+6m in very exposed environments

It is how often these levels are expected that is different. The frequency with which the sea levels for exposed and very exposed environments are reached will depend upon the frequency expected for severe storms. It is possible that, with climate change, severe storms will become more frequent, and so the critical levels may well be reached more often in the future.

On the other hand, the critical sea level of LLD+1.5m in sheltered coastal environments will definitely be reached more frequently. By 2030, these levels are likely to be reached every year. This has implications for the coastal defences that will be needed to provide adequate protection for the sheltered environments. A further concern is the possibility of drastic change if the protection afforded such a sheltered environment is destroyed. Then the coast will be exposed to the much higher sea levels associated with severe storms. The new coastal defences that will then be needed are likely to be massive, and to be costly to erect and maintain. Future economic growth in Namibia will likely be a deciding factor in determining the appropriate approach by the authorities.

4.4. **Third study: Sea level rise scenarios along the coastline of Namibia after collapse of the polar ice sheets**

The timing of future sea level rise in the longer term is problematic. The Intergovernmental Panel for Climate Change has withdrawn any upper bound estimate to its forecasts of sea level rise over the 21st century. However, in the two year period since the publication of the *IPCC Synthesis Report (Nov 2007)*, worrying signs have appeared of an acceleration of climate change effects. After the International Scientific Congress on Climate Change, held at the University of Copenhagen from 10-12 March 2009, a number of Key Messages were released, <http://climatecongress.ku.de>, including:

Key Message: Climatic Trends

Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realised. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.

This strengthens the need to investigate more extreme sea level scenarios.

An alternative and preferable approach for the longer term future is to link sea level rise to the possible stabilization levels of greenhouse gases in the atmosphere and the accompanying global warming and polar ice melt. This is the approach which is recommended in the *Stern Review (2006)*, and then followed in the IPCC Synthesis Report, *IPCC AR4 (Nov 2007)*.

The following linkages of climate change are expected from the sets of climate models which are used in the *Stern Review (2006)*. It should be noted that the present level of carbon dioxide equivalent is at 380ppm, and rising. Any stabilization level will require urgent global action on constraining the input of greenhouse gases into the atmosphere.

4.4.1. Scenario A.

450ppm carbon dioxide equivalent stabilization level
2 degree Celsius temperature rise
1m sea level rise from thermal expansion only
Rising intensity and frequency of storms
Onset of irreversible melting of the Greenland Ice Sheet
Initiation of further sea level rise as the melting progresses

4.4.2. Scenario B.

550ppm carbon dioxide equivalent stabilization level
3 degree Celsius temperature rise
1.5m sea level rise from thermal expansion only
Significant contribution to sea level rise from the Greenland Ice Sheet
Increasing risk of collapse of the West Antarctic Ice Sheet
Sea level rise of a few metres

4.4.3. Scenario C.

750ppm carbon dioxide equivalent stabilization level
4 degree Celsius temperature rise
2m sea level rise from thermal expansion only
Yet more storminess
Onset of collapse of the West Antarctic Ice Sheet
Eventual sea level rise of over ten metres

These linkages are illustrated with median levels of each quantity; there are considerable spreads about these median levels. Lower stabilization levels are unlikely. It is important to recognize that no time scales are provided for these scenarios. However, the gradual progression of climate change through the stabilization levels, global warming and polar ice melt will provide better estimates of the timing and extent of global sea level rise.

The *IPPC Synthesis Report (2007)* follows the *Stern Review(2006)* and considers projections of future climate change over and beyond the 21st century. Rapid sea level rise on century time scales cannot be excluded. Net ice loss will set in with a global average warming in excess of 2 degrees Celsius, marking the onset of an accelerating ice melt contribution to sea level rise. The complete elimination of the West Antarctic Ice Sheet will eventually lead to a contribution to sea level rise of 5m. These temperatures correspond to those of the last inter-glacial of 125000 years ago, when sea level was 4 to 6 m higher than present levels.

The prime effect of the rapid sea level rise over the longer term future is the permanent inundation of low lying coastal areas, rather than the intermittent effect of storm damage. As sea level rise continues, it will lead to the wholesale disruption of services along the coast. In a study of the implications of a sea level rise of 5m for three large estuaries of Western Europe, *Tol et al 2006*, retreat from the coastal zone and the abandonment of coastal land at risk, was considered a more

cost effective option than large and expensive coastal defences. This was the preferred option even for the Western Netherlands with its long history of combating sea level rise.

4.4.4. **Scenario Three: The Polar Ice Sheet Melt Scenario**

When wholesale melting of the Greenland and West Antarctica Ice Sheets begins to contribute to sea level rise, the anticipated levels will be greatly in excess of earlier levels. This leads to the **Polar Ice Sheet Melt Scenario**. There is much uncertainty about the extent and the timing of the melting of the polar ice sheets and their eventual contribution to sea level rise and coastal inundation. Consequently, this Scenario Three is fundamentally different from the earlier scenarios. The focus should be on Mean Sea Level and the changes to be expected from the ice melt alone, so as to provide an every day scenario for these circumstances. It will map the location of the new coastline. Tides and storms can be added later, if need be, to illustrate the variability to be expected on a day by day basis.

Because storms are excluded, there is now no difference between sheltered and exposed sections of coast; all experience the same level of inundation by the sea. In this Polar Ice Sheet Melt Scenario, the important information will be the **order** in which different land areas are overwhelmed in the inexorable rise in sea level. Digital Elevation Maps can be used to provide this information at, for example, LLD+1m, LLD+2m, LLD+3m, LLD+4m, and LLD+5m. Emphasis can then be placed on separate categories of infrastructure and services, such as loss of industrial areas, residential areas and disruption of the transport networks. The information on the order in which disruption will occur will aid in preparation for adaptive planning for the very worst consequences of sea level rise on Namibia. Remember that there is great uncertainty on the timing of such a long lead time scenario; this is a scenario not a prediction.

4.5. **Fourth study: Sea level rise impacts along the coast of Namibia, with an emphasis on Walvisbay**

In a World Bank study of the impact of sea level rise on developing countries worldwide, *World Bank 2007*, sub-Saharan Africa is noted to have the least impact of all regions. Even within this region, Namibia is not ranked highly. In terms of the proportion of the country area impacted by sea level rise, Namibia is ranked 22 out of 29 coastal countries in sub-Saharan Africa. The ranks for other impacts of sea level rise are rank 16 for population impacted, rank 27 for proportion of Gross Domestic Product impacted, rank 22 for urban extent impacted rank 26 for agricultural extent impacted and rank 26 for wetlands impacted. All these impacts are proportional and are ranked with respect to the 29 coastal countries of sub-Saharan Africa.

For Namibia, the ranks of most concern are for population impacted and for urban extent impacted. The major centres of population along the Namibian coast are Oranjemund (2001 population 5,451), Luderitz (13,276), Walvisbay (42,015) and Swakopmund (25,442). There are only small settlements along the coast in Northern Namibia.



Figure 13: Oranjemund on Google Earth

Oranjemund is set well back from the coast, whilst its approach roads are at risk from the Orange River rather than the sea.



Figure 14: Lüderitz on Google Earth

Lüderitz is built on a steep rocky shore (*Theron 2007*), and is protected by the bulky headland of Diaz Point.



Figure 15: Swakopmund on Google Earth

Swakopmund is located on relatively high ground, to the north of the mouth of the ephemeral Swakop River.

For Oranjemund, Luderitz and Swakopmund, sea level rise only poses a possible threat in the long term. However, for Walvisbay, the threat is immediate.



Figure 16: Walvisbay on Google Earth

Walvisbay is low lying with much of the town at an elevation of less than 2m above mean sea level. The town is situated on the eastern side of the bay, to the north of the estuary of the ephemeral Kuiseb River. It is protected from the open sea by the 10km long sandspit terminating in Pelican Point. Walvisbay is the principal harbour of Namibia, through which most of its trade passes, and is the third largest urban centre in the country. It is the vulnerability of Walvisbay to the impacts of sea level rise that contributes most to the World Bank ratings of concern in Namibia.

An earlier study by *Hughes et al 1992* provides valuable insights into the nature of the risks from sea level rise at Walvisbay, with four categories of potential impact being considered; increased coastal erosion, flooding and inundation, increased saline intrusion and raised water tables, and reduced protection from extreme events at sea. Their conclusions were that increased coastal erosion, whilst it would occur, would not be a threat as urban development has not taken place in the most dynamic and vulnerable parts of the coastline. Similarly, the increased intrusion into the Kuiseb aquifer can be managed and accommodated by judicious freshwater extraction. Of greater importance is the possibility of inundation, waterlogging and flooding of the town of Walvisbay, particularly if the protection from the Pelican Point Sandspit is reduced.

There are two quite different situations, which need to be considered separately. The first is if the protective Pelican Point Sandspit remains in place and the town and harbour of Walvisbay remains a sheltered environment; and the second is if the Pelican Point Sandspit is breached and Walvisbay is exposed to the full impact of storms from the sea.

4.5.1. Impact on Walvisbay as a Sheltered Coastal Environment

In a sheltered coastal environment, the extreme sea levels as measured on tide gauges and presented in the form of a Port Diagram are relevant to the expected extreme sea levels at long return periods.

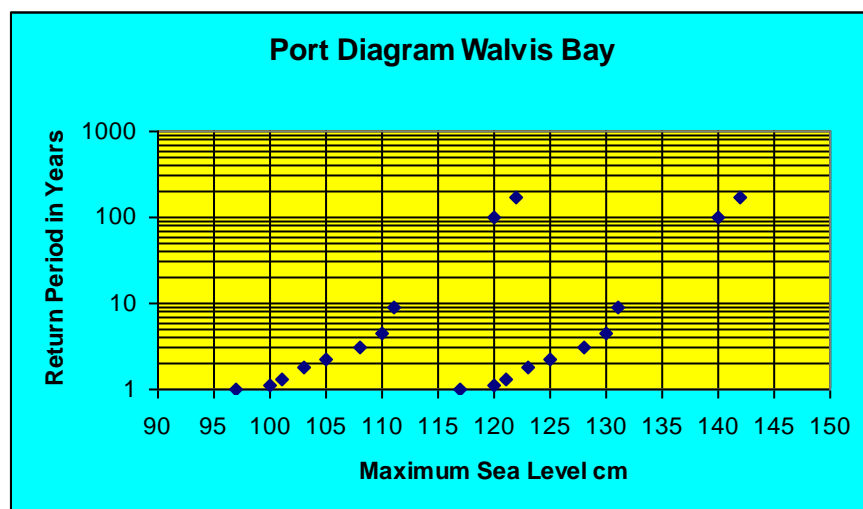


Figure 17: Port Diagram for Walvisbay, at Present and Projected for the Year 2030

The present Day Port Diagram shows extreme sea levels at Land Levelling Datum+100cm on an annual basis, at LLD+111cm at a return period of 10 years and at LLD+120cm at a return period of 100 years. These extreme sea levels can be used with profit if a Digital Elevation Map (DEM) of Walvisbay is available. Land elevations at these extreme sea levels contoured on such a DEM of Walvisbay, will show the land areas which are at risk at these same return periods. If the DEM also provides details of population and municipal services within the municipal area of Walvisbay, the population and infrastructure at risk will become clear.

Whether the risk will become a reality depends on the protection level of existing coastal defences. Protection levels can be categorized, *Nicholls and Tol 2006*. For Walvisbay,

Minimal Protection is afforded by coastal defences maintained at a height of LLD+100cm which corresponds to the extreme sea level expected to occur annually, Low Protection by coastal defences at a height of LLD+111cm which corresponds to the extreme sea level expected at a return period of 10 years, and Medium Protection by coastal defences at a height of LLD+120cm which corresponds to the extreme sea level expected at a return period of 100 years. Existing high value infrastructure along the coast within the town of Walvisbay should be protected by coastal defences at a Medium protection level rather than a Low or Minimal Protection level. If the high value infrastructure is not protected at the Medium Protection level, the alternative is to take out insurance to guard against the damage which would follow the flooding of low-lying areas from a storm with a return period of 100 years.

The sea level rise of 20cm, expected by 2030, will alter the detail of the Port Diagram for Walvisbay, in that particular extreme sea levels will occur much more frequently. Thus in 2030, an extreme sea level of LLD+120cm will likely occur on an annual basis, rather than occurring on a return period of 100 years as at present. The population and infrastructure at risk from an extreme sea level of 120cm will also be threatened on an annual basis. In order to maintain coastal defences at the present day heights, the protection will have to be raised by 20cm by 2030, in line with the expected sea level rise. Continued development in the town, and investment in infrastructure and services, may well mean that existing protection levels should be increased to the Medium Protection level, all along the coast of Walvisbay. In 2030, the Medium Protection level will require coastal defences at a height of LLD+140cm.

Raising, strengthening, maintaining and improving the coastal defences on the coast within the town of Walvisbay, will require ongoing cost-benefit assessments of the continuous expenditure from the relevant authorities. It may be helpful to report on a global study of the affordability in developing countries of accepting various protection levels of coastal defences, *Nicholls and Tol 2006*. In general terms, an economy with Gross Domestic Product per capita below US\$600 will not be able to afford coastal defences at the low protection level. On the other hand, coastal defences at the medium protection level will require an economy with GDP per capita approaching US\$2400. Further, whilst universal coastal protection may not be affordable at present in many developing countries, the prospects will improve in a globally favourable economic climate and better protection may well be possible by 2030. In such circumstances, *Nicholls and Tol 2006* believe that most developing countries will be able to afford optimal protection against the impacts of sea level rise.

It is worth commenting on the set-back accompanying sea level rise on those parts of the coast within the sheltered confines of Walvisbay, which is due to enhanced coastal erosion. For example, *Hughes et al 1992* have calculated the likely coastal set-back from coastal erosion at a number of offshore profiles, both outside and inside Walvisbay, as shown in Figure 18. At profiles 5, 6 and 8, the set-back for a sea level rise of 20cm is estimated at almost 100m. Such levels of set-back may well not be acceptable, and so previously unprotected parts of the coastline may need to have new coastal defences built to prevent erosion close to the town of Walvisbay itself.

4.5.2. Impact on Walvisbay as an Exposed Coastal Environment

This is the situation where Walvisbay loses the protection of the Pelican Point Sandspit to the west, and becomes exposed to the full impact from storms at sea. Such a loss of protection can come about as a result of these storms breaching the sandspit, or from sea level rise leading to the overwhelming of the sandspit.

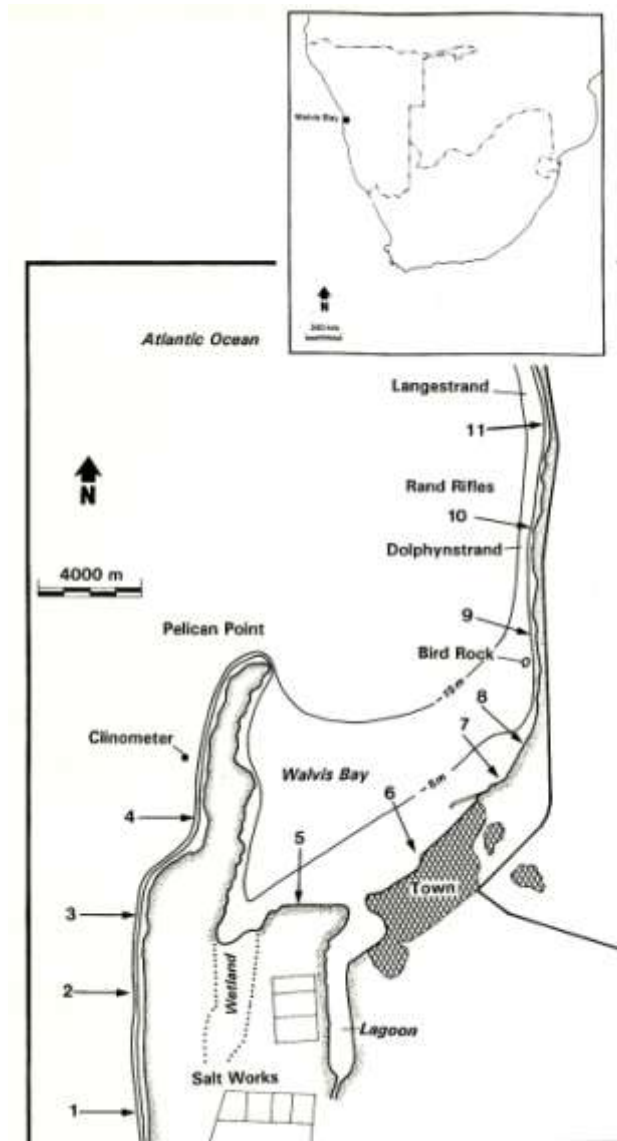


Figure 18: The location of Walvisbay (from Hughes et al 1992)

The sandspit on the western side of Walvisbay and terminating in Pelican Point is some 10km long and has an average height of 1m. It is subject to washover in severe storms, which led to a partial breach in 1999, *Theron 2007*. With even small rates of sea level rise, there is a growing threat of a wide and permanent breach in the Pelican Point Sandspit. Experiences from similar situations along the Namibian and Angolan coasts are relevant. The sandspit at Sandwich Harbour, to the south of Walvisbay, was recently breached, with the rapid loss of previously protected wetland.

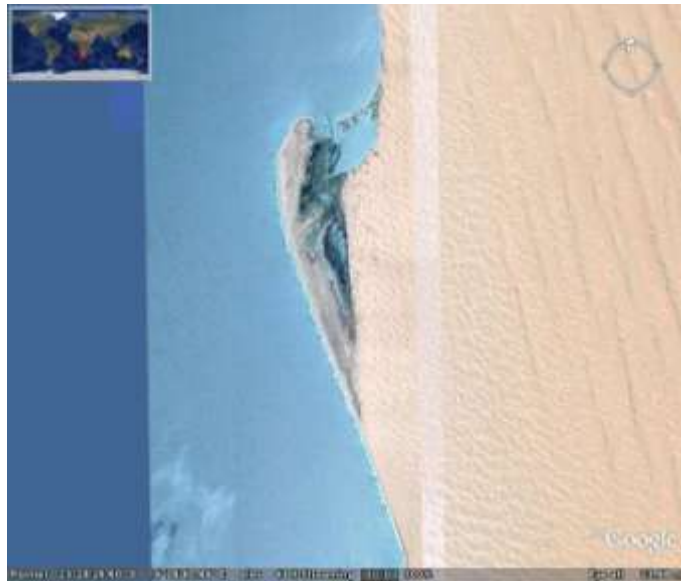


Figure 19: Sandwich Harbour on Google Earth

Of more concern was the 11km breach in the 41km sandspit at Baia dos Tigres in southern Angola, which has led to the exposure to the sea of the previously protected coast, *Theron2007*.



Figure 20: Baia dos Tigres, southern Angola on Google Earth

Returning to the situation of the sandspit to the west of Walvisbay, where deep water is found close to a steeply shelving beach, the coast is very exposed and waves can erode the face of dunes on the beach. The observations from the KZN storm of March 2007 suggest that the most extreme storm expected at present on the sea side of the Pelican Point Sandspit, will reach an erosion line of LLD+400cm to 500cm, and a swash line of LLD+700cm, and will cut back the dune by 20 to 30m. Measurements taken at Oranjemund confirm these suggestions, as wave run-up commonly reaches LLD+410cm and on occasion reaches LLD+470cm (*Theron 2007*). Such a storm would certainly swamp the Pelican Point Sandspit, and would possibly lead to a permanent breach.

Sea level rise, even at the modest level of 20cm by 2030, would accentuate the threat, because of the enhanced coastal erosion that will accompany sea level rise. For example, *Hughes et al 1992* have calculated the likely coastal set-back from coastal erosion at a number of offshore profiles, both outside and inside Walvisbay, as shown in Figure 18. For profile 4, on the exposed coast, sea level rise of 20cm would lead to set-back of 18m, whilst sea level rise of 100cm would lead to a set-back of 90m. Such coastal set-backs will increase the vulnerability of that particular stretch of coast to breaching at the time of an extreme storm, with its own additional set-back of 30m.

In addition, sea level rise will raise the water table in the wetlands inside the bay, and result in the increased possibility of erosion of the water-logged areas. This can be illustrated through changes in the coastline following sea level rise of 100cm.

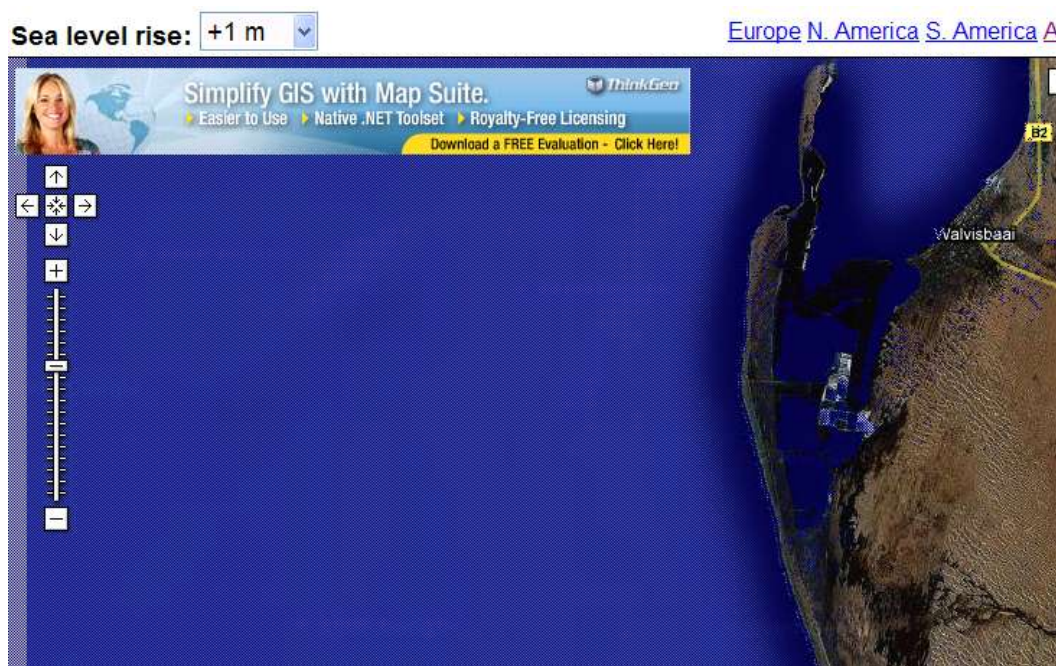


Figure 21: Walvisbay after 1m sea level rise, from www.flood.firetree.net

The wetland areas to the south of the bay are now inundated, leading to a vastly increased possibility of breaching of the sandspit.

With the protection of the Pelican Point Sandspit removed, Walvisbay can no longer be considered to be a sheltered environment. The town and harbour will be located on an open coast, exposed to greatly enhanced wave activity.

Return period	1 Year	10 Years	100 Years
Walvisbay	3.6m	4.4m	5.2m

Table 4: Deep Water Significant Wave Heights for offshore of Walvisbay.

With no additional protection, the set-up from such waves is estimated at 30% of the significant wave height. The town of Walvisbay will be subject to sea levels of $LLD+100+108\text{cm} = LLD+208\text{cm}$ on an annual basis, and of $LLD+276\text{cm}$ from extreme sea levels with a return period of 100 years. Such an extreme sea level will inundate much

of the town. The coastal defences needed to protect the town of Walvisbay in this exposed situation, are much greater, extensive and costly.

It is clear that an assessment is needed of the measures that will ensure the continued viability of the Pelican Point Sandspit. Defences could involve extensive coastal engineering, with the possibility of sand nourishment, groynes, rock revet units and sand-filled geo-textile shore protection, *Theron 2007*.

4.5.3. **Consequences of the Polar Ice Melt Scenario**

The consequences of the onset of polar ice melt and sea level rise of metres along the coast of Namibia are profound, particularly as this will be accompanied by extensive set-back and remodelling of the coastline. There will be impacts on all infrastructure on the coast and on all activities that take place along the coast. As there will be warning of such a huge sea level rise, and time to adapt, it will be important to plan ahead, explore the possible adaptation options and put appropriate policies in place. Specific areas that will need attention are the implications for the onshore and offshore diamond industry, for coastal tourism, and the implications for urban settlements, particularly Walvisbay. Rather than trying to protect the present infrastructure with massive, and overwhelmingly expensive, coastal defences, the option of managed retreat from the coast should be explored. The harbour, and its facilities and services, will need to be continually rebuilt on higher ground as the sea rises, taking care that each new location is adequately protected from the open sea. The town of Walvisbay will likely be relocated further up the Kuseb River, keeping it close to its source of fresh water.

5. Analysis of Impacts

By Danie Nel (Lithon Project Consultants, July 2009)

Identification of impacts of sea level rise and storm surges on humans (socio-economics and infrastructure)

5.1. Methodology

5.1.1. In determining the required outcomes, adaptations and mitigation strategies, it was identified that firstly the baseline conditions would need to be established. Furthermore the nature and extent of the climate and environment changes would need to be determined with reference to how they impact the sea level at the Namibian coast. These changes were projected on the baseline to then determine impacts and these impacts were extrapolated to account for future impacts, taking expected growth and future planning into account. Future scenarios were based on historical data and planning, where available. The impacts were then assessed accordingly, in terms of infrastructure, socio-economic, fresh water and environmental (biodiversity etc.). The outcomes to this process were used to identify vulnerabilities and develop adaptation and mitigation strategies in cooperation with local stakeholders.

5.1.2. Scenario planning:

Actual sea-level rise along the Namibian coastline depends on a range of weather, climate and tide influences. Both weather and climate are being influenced by changing concentrations of greenhouse gases. Given the range of social and biophysical influences that will determine future sea-levels, it is difficult to predict exact sea-levels at specific times. It was decided that this study should apply three scenarios, all of which are within the range of scientific probability, to examine possible sea level rise impacts upon the Namibian coastline. The three scenarios involve:

1. The baseline: 100-year storm scenario – this is based on existing mean sea levels and current worst case storm levels. It includes the 0.2 metre sea-level rise that has taken place in the last century
2. Year 2030 – this model is based on projections of sea-level rise under business-as-usual greenhouse gas emissions.
3. Three specific atmospheric greenhouse gas concentration level models – these are based on projections of various climate change models, without specific timings, due to expected long time spans involved and thus the variability in such projections.

Specifically, the three scenarios were chosen because:

Scenario 1: Describes the current worst case scenario, to support the baseline requirement;

Scenario 2: Gives a planning goal (fixed time) that is far enough to effectively plan towards, but is near enough to provide a realistic forecast;

Scenario 3: Provides worst case scenarios that could support long term planning and “worst case scenario planning”.

5.1.3. Terminology employed in this report:

- a. Storm surges: These are intermittent occurrences during storm or storm-like conditions where the sea levels reach extraordinary levels. During such conditions the sea may achieve extremely high levels in certain, highly localised areas. The average maximum sea levels attained at such times also tend to vary between geographic locations for various reasons.
- b. Sea level rise: The terms describe a permanent increase in the mean sea level (also called "land levelling datum"), which is more or less consistent along the length of the Namibian coastline. Intermittent storm surges would act to increase mean sea-level for the duration of the storm.
- c. Where monetary values are expressed in terms of "loss" it is implied that any capital investments made would be irrecoverably lost and that there would not necessarily be any further costs incurred. "Loss" in this sense is defined as **a loss of invested capital**, and not economic impact.
- d. Where such values are expressed as "costs" it is implied that the equivalent amount would have to be expended to reinstate the service(s) delivered by the infrastructure lost or damaged due to sea level rise.
- e. Sheltered, exposed and very exposed environments describe the degree to which certain coastal environments would be impacted by storm (i.e. intermittent) sea levels, not average sea levels.

5.1.4. Project implementation background

This section of the report was compiled with the aid of two young Namibian engineering technicians, who were exposed and gained an understanding of the reality and possible dangers of sea level change, as well as the extent of possible, unmitigated impacts.

5.2. Global environmental analysis

A study of global weather patterns and forecasts for future temperature rises was done to determine the impact of climate change on storm frequency / severity, polar icecap melts and thermal expansion of seawater, which would indicate median and maximum expected sea levels and level frequencies for the Namibian coast.

Future sea level rise and storm surge impacts along the Namibian coast were considered under three scenarios:

- Scenario One: The present day worst case scenario for the coastline of Namibia
- Scenario Two: The sea level scenario at 2030
- Scenario Three: Three atmospheric CO₂ concentration levels including: a polar ice sheet melt scenario

The consulting team relied on the twenty years of sea-level data from both Lüderitz and Walvisbay that is held at the SAN Hydrographic Office in determining the sea level rise and storm surge predictions, as well as information from the IPCC, World Bank, UNFCCC, South African Navy and others.

It was initially determined that sea level rise would impact the following human settlements in varying degrees (from most to least populace):

- Walvisbay – Sheltered environment
- Swakopmund – Exposed environment
- Lüderitz – Sheltered environment
- Hentiesbay (and Wlotzkasbaken nearby) – Very exposed environments
- Long Beach and Dolphin Beach – Exposed environments

It was also determined that the following settlement would not experience direct impacts:

- Oranjemund

Environmental mapping would have to be done to determine the extent and range of impacts on fauna and flora along the Namibian coast.

5.3. Map analysis

The sea level rise data from the global environmental analysis was mapped onto contour mapping to obtain “extent of impact” maps (i.e. to relate the vertical changes in sea levels into horizontal ingress). Various areas were demarcated according to level and extent of impact. The damage was calculated in terms of present value cost for 2009 and in 2030 value for damages then and thereafter (since it is the last definite date in terms of planning).

The probability of each scenario manifesting at discrete locations at some stage in the next 25 years was estimated based on expert opinion and the available international projections of sea-level changes. It should be noted that these probabilities contain inherent uncertainty (see Figure 22). It is not possible to “predict and provide” in terms of sea-level rise impacts and appropriate responses and this needs to be considered in drawing inference from this study and formulating responses. At the same time some level of probability is required to inform decision makers and calculate risks.

For the purpose of this study it is assumed that:

- Scenario 1 has a 95% chance of occurrence in the next 25 years. With increasing mean sea-level and increasing intensity and frequency of storms, it is almost certain that the discrete points included in this study on the Namibian coast will be buffeted by at least one storm with this impact over the next 25 years. During this time it is certain that mean sea-level will be at least 35 cm above the long-term mean – a level that will affect the energy with which wave and tidal surges approach the coast.
- Scenario 2 has been constructed as the likely prevailing scenario in 10 to 21 years time, and reflects the current worst case scenario with abbreviated return times. We cannot be sure of exactly how the frequency with which these events occur will be truncated but at the current moment Scenario 2 is assumed to have an 85% probability of occurring in the next 25 years for each of the locations in this study.
- Scenario 3 is linked to longer term drivers associated with the melting of polar ice sheets. Until recently this scenario was considered unlikely this century, but that has changed. It is assumed

that Scenario 3 (a) will have a 20% chance of occurring in the next 25 years, in which case it would affect all locations in this study simultaneously.

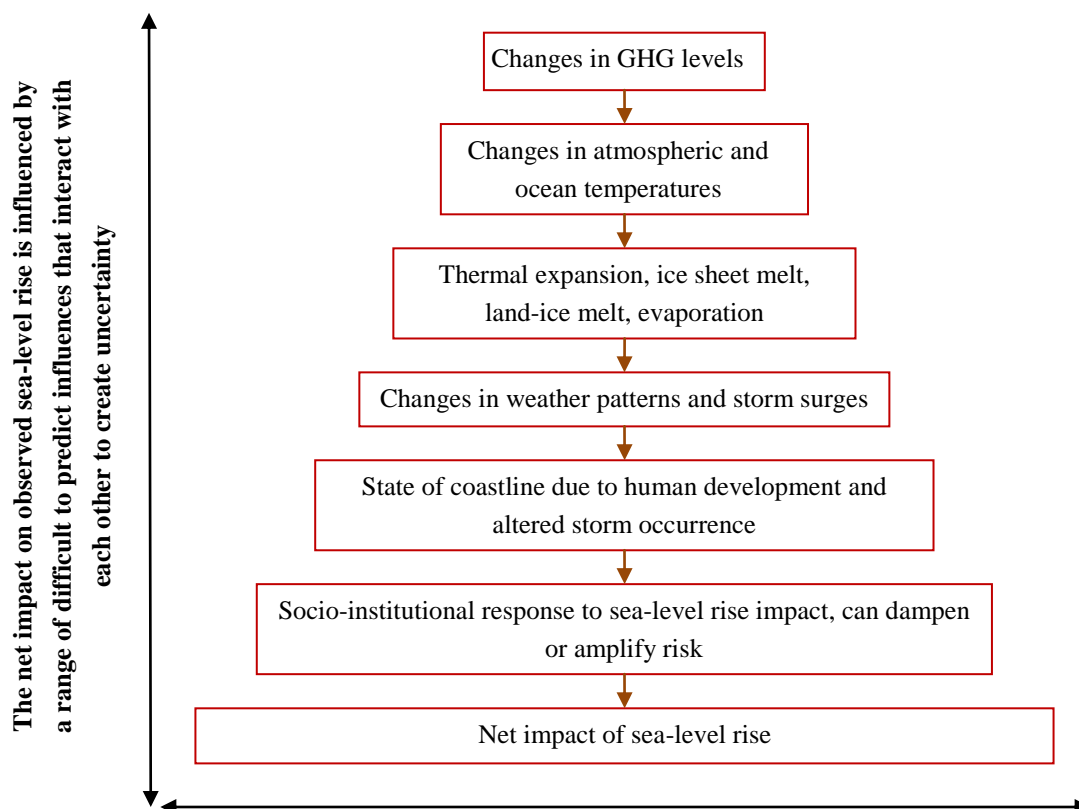


Figure 22: Uncertainty and risk increase with added layers of complexity

Figure 19 shows the “cascade of uncertainty” that is a feature of all climate change risks. Some of this uncertainty arises from natural variability while other uncertainty arises from incomplete knowledge (Hulme and New, 2001).

Satellite photos were also evaluated in lieu of detail mapping outside of the towns to establish the availability of future, useable land; and more specifically those areas that are useable and would be impacted / reduced by sea level rise. The purpose was to establish lost opportunity costs, due to not being able to develop these areas in future: this is an important factor in the growth of the towns.

5.4. Socio-economic background study

5.4.1. Namibian national socio-economic figures

- a. Annual inflation in the Namibian context is often taken as 10% per annum. The real average value for the ten years prior to end of 2008 was 7.3%. There was a strong trend, starting in May 2008, for the increase in inflation (which may be linked to the global economic crisis of 2008). The early 2009 levels persisted around 11-12%. A figure of 10% (the assumed value for this report) would imply that the financial figures given later would double in value every six to seven years after 2009.
- b. The average annual economic growth for Namibia for the ten years prior to 2009 was 3.5% (before the subsequent economic crisis). The economic crisis was estimated to have caused a severe reduction in the growth rate of the economy in 2009, with some

economists stating that it was likely to contract. Economic growth at 3.5% (the assumed value for this report), in a very simplified economic model, would imply that the local economy would double in value every 21 years. This is a relatively long time scale and variation should be expected.

- c. Namibia's annual population growth rate is reported by various sources to be between 0.95% and 3%. Historic survey data indicated a growth rate of 2.6% in 2001. At approximately 1%, the population growth rate would imply a doubling in the country's population approximately every 70 years. At 3% (the assumed value for this report) it would only double every 24 years. These are very long time scales and variation in the growth rate is to be expected.
- d. The annual per capita GNI for Namibia was US\$3,360 (\pm N\$30,240) in 2007.
- e. The annual per capita GDP for Namibia was US\$5,300 (\pm N\$47,700) in 2007.
- f. Property value growth has been discounted in this report, due to the high variability between different areas and different periods. The Namibian property market at the coast has historically been in a growth pattern (for the 10-15 years prior to the 2008-9 economic crisis), with periods of stabilisation; only experiencing price contractions (not considering the impact of inflation) in certain locations.

5.4.2. Walvisbay

- a. Walvisbay is Namibia's largest coastal town and most active port. It is not as dependant on tourism as some of the other coastal towns, but has an active economy based on port activities and also expanding into industrial and power generation activities.

Nature of economic activity

- b. Economic activity in Walvisbay is centred on the local port, acting as a shipping and fishing industry hub. Walvisbay has a well developed infrastructure, catering to the shipping activities of the port as well as industries around the town. There are portions of land nearby which have been declared as EPZs in the hope of attracting more industrial development. The fishing industry has come under increasing pressure due to decreasing marine resource availability. Walvisbay also hosts a large salt works facility. One of the most important functions of the port is the importation of liquid fossil fuels, which are critical components of the national economy (Namibia is a net importer of the majority of all local goods, including foodstuffs via road, rail and shipping).
- c. Walvisbay's 2007 population was approximately 42,015 and the average population fluctuation is not as seasonal as Swakopmund, or other coastal holiday towns.
- d. It was determined that Walvisbay had total of approximately 10,914 properties in 2008/9; also counting those extensions that are more inland (\pm 1,436 properties) and the separate beachfront extensions (\pm 441 properties) to the north of Walvisbay.
- e. Hence, using the 2007 GDP, the economic activity (GDP) in Walvisbay would have been approximately N\$1.992bil in 2007 (this does not account for the value of goods passing through the port); and N\$2.133bil in 2009. This is a rather simplistic model

and it can be assumed with the high level of economic activity, as compared to other population centres in Namibia, the true figure would be significantly higher.

Projected development

- f. Walvisbay will most likely grow at the same rate as the national average economic growth rate, unless a surge in especially industrial investment occurs, which could boost growth.
- g. There are currently plans for the construction of a large coal-fired power station near Walvisbay, which would boost economic growth. The project is in the advanced stages of an EIA.
- h. The northern extensions of Walvisbay, such as Dolphin Beach and Long Beach still offer ample opportunity for beachfront development. The development here is occurring at a rapid pace.
- i. There are also the ample open areas still available around Walvisbay, and this should ensure the availability of overall development space. The scarcity of beachfront property is not as pressing as in Swakopmund, but perceived scarcity especially in the northern extensions of Walvisbay has created property values that nearly match those of Swakopmund.
- j. Given the availability of resources in the preceding argument, the economy of Walvisbay should develop to an approximate GDP level of N\$4.394bil by 2030 (future value), at 3.5% growth. The total growth by that date, from 2009, would be 106%, indicating a doubling in size of the Walvisbay economy and most likely a doubling in physical size.
- k. The size if the current town and surrounding farm lands can accommodate the abovementioned growth, though some reclamation of desert areas would be required. The details of Annex II should be noted with regard to sea level rise and the extensive "set-back" (i.e. erosion) of land mass due to small increments of the sea level.

5.4.3. Swakopmund

- a. Swakopmund is a scenic coastal town, Namibia's second largest, with an economy based on tourism, realty and support of the local uranium mining industry, which has been rapidly expanding since 2007.

Nature of economic activity

- b. Economic activity in Swakopmund is fairly limited to servicing the small local population (though the available services are reasonably diverse), tourists and the active building industry. Tourism is based on the town's extensive history and scenic nature as well as temperate climate. The town is quite central (between Walvisbay, Wlotskasbaken and Hentiesbay) and offers good shopping opportunities for holiday makers. A large part of the local economy is dependent on the local uranium mines and salt works (primary industries) and rendering services to the same. There is a significant seasonal fluctuation to the local population due to the town's popularity as a holiday destination.

- c. Developments in the western parts of Namibia, in finding and exploiting numerous uranium reserves, would likely boost the economic growth in these areas beyond the national historic figure of 3.5% pa.
- d. Swakopmund's 2007 population was approximately 28,552, with high seasonal variation due to its status as a holiday destination.
- e. It was determined that Swakopmund had total of approximately 10,311 properties in 2008/9, including the Mile 4 extension; and also counting those extensions that are more inland: DRC ($\pm 1,470$ informal properties) and Mondesa ($\pm 3,700$ properties including all extensions).
- f. This means, using the 2007 GDP, that the economic activity (GDP) in Swakopmund would have been approximately N\$1.353bil in 2007 (the use of this simple calculation is supported by the very basic level of economic activity); and N\$1.449bil in 2009.

Projected development

- g. Swakopmund will most likely have a higher than [national] average economic growth, due to the influx of humans and investment caused by mining activities in the 21st century.
- h. Further large scale development of properties along the beachfront is unlikely, given the proximity of the large salt processing plant and the limitation of the town boundaries. Unless the town boundaries are extended and / or the salt works relocated, further beachfront development will eventually come to a halt.
- i. Given the ample open areas still available around Swakopmund, scarcity of overall development space is not seen as a significant factor. The scarcity of beachfront property will more likely channel investment interest to other areas (and will also be the price driver of these properties). This in turn may reduce the overall attractiveness of Swakopmund in an aesthetic sense, but up to that time, Swakopmund may already have developed sufficient secondary and tertiary industry capacity to fuel further growth.
- j. Given the foregoing, the economy of Swakopmund should develop to an approximate GDP level of N\$2.984bil by 2030 (future value), at 3.5% growth. The total growth by that date, from 2009, would be 106%, indicating a doubling in size of the Swakopmund economy and most likely a doubling in physical size. The size if the current town lands could accommodate this growth, although the presence and position of the salt works would exclude further significant beach front development (up to 15m above median 2009 sea level, which is already significantly inland).

5.4.4. Lüderitz

- a. Lüderitz a small, scenic town on the south western coast of Namibia, near the famous abandoned diamond mining town of Kolmanskop. The town consisted of approximately 3,598 properties at the time of the report, with a large percentage of available land taken up by industrial zoned stands.

Nature of economic activity

- b. Much of the local economy is based on the local port, which handles considerable volumes. Tourism and industry are also an important activities in this economy. One of the most important functions of the port is the importation of liquid fossil fuels, which is a critical component of the local & national economy; and also the export of zinc and sulphur.
- c. Lüderitz's 2007 population was approximately 12,139 and the average population fluctuates with seasonal holiday makers.
- d. It was determined that Lüderitz had total of approximately 3,598 properties in 2008/9; including those extensions that are more inland.
- e. Hence, using the 2007 GDP, the economic activity (GDP) in Lüderitz would have been approximately N\$575mil in 2007 (this does not account for the value of goods passing through the port); and N\$616mil in 2009. This is a rather simplistic model and it can be assumed with the relatively high level of economic activity, the true figure would be significantly higher.

Projected development

- f. Lüderitz may grow at the same rate as the national average economic growth rate, unless a surge in especially industrial or port investment occurs, which could boost growth.
- g. There are currently plans for the construction of a relatively large wind power installation at Lüderitz, which would boost economic growth.
- h. There are open areas still available around Lüderitz, but the surrounding diamond areas ("Sperrgebiet") limits development. Lüderitz's rocky shoreline implies that beachfront property is not a key economic factor.
- i. Given the availability of resources in the preceding argument, the economy of Lüderitz may not develop to the approximate GDP level of N\$1.27bil by 2030 (future value), that would otherwise be reached at 3.5%pa growth. At this rate of growth, the total growth by that date, from 2009, would be 106%, indicating a doubling in size of the Lüderitz economy and most likely a doubling in physical size.
- j. It is unclear whether this growth could be supported by the available town and farmlands.

5.4.5. Hentiesbay

- a. Hentiesbay is a very small, town 70km north of Swakopmund. The local economy almost entirely relies on tourism, with high seasonal population fluctuations. The town consisted of approximately 2,633 properties at the time of the report, mostly residential, with some light industry and light commercial.

Nature of economic activity

- b. Tourism and light industry are the most important activities in the Hentiesbay economy. Tourism centres on sport and recreational fishing as well as camping and desert-adventure activities. Hentiesbay is also seen as a family holiday destination.

- c. Hentiesbay's 2007 population was approximately 3,000 and the average population fluctuates with seasonal holiday makers.
- d. It was determined that Hentiesbay had total of approximately 2,633 properties in 2008/9; including those extensions that are more inland.
- e. Hence, using the 2007 GDP, the economic activity (GDP) in Hentiesbay would have been approximately N\$142mil in 2007 (this does not account for the value of goods passing through the port); and N\$152mil in 2009. This is a rather simplistic model, but applicable due to the town's basic economy.

Projected development

- f. Hentiesbay may grow at the same rate as the national average economic growth rate, unless a surge in especially industrial and commercial sectors occur, which could boost growth.
- g. There are abundant open areas still available around Hentiesbay for further development and beachfront property availability is apparently limited only by town planning.
- h. The economy of Hentiesbay may not develop to the approximate GDP level of N\$313mil by 2030 (future value), that would otherwise be reached at 3.5%pa growth. At this rate of growth, the total growth by that date, from 2009, would be 106%, indicating a doubling in size of the Lüderitz economy and most likely a doubling in physical size.
- i. It is unclear whether this growth could be supported by the available town and farmlands.

5.5. Assumptions

- 5.5.1. Due to the many uncertainties, economic and population growth figures have been reduced to conservative single figures to expedite calculations.
- 5.5.2. As for above, in calculating property and infrastructure impacts, certain industry-average values have been used to calculate costs.
- 5.5.3. In the case of cost calculations of properties, industrial, commercial and residential were treated equally and averaged year-2009 replacement / repurchase rates were used.
- 5.5.4. To aid comparison, monetary values have been expressed in the baseline year, net of inflation and interest, but including growth.
- 5.5.5. In the following section of the report, the impacts of sea level rise will be analysed with reference to each of the major human settlements along the Namibian west coast, for each of the identified scenarios. Oranjemund is not considered due to the certainty that it will be safe from the direct effects and impacts of sea level rise.
- 5.5.6. It is not envisioned that there would abrupt changes in the sea level that would result in catastrophic loss of life. Mean sea level rise is expected to occur over sufficiently long periods of time to allow for the planning and implementation of adaptation or mitigation

- strategies. This does not preclude the possibility of life threatening storms developing as the global and therefore local climate changes.
- 5.5.7. There is an economic, positive feedback mechanism that has not been considered in the economic studies of this report. This effect, in the case of the sea level impact study, would mean that negative investment sentiment towards the coastal towns (because of perceived risks due to climate change) leading to reduced investment or divestment, could start a positive feedback cycle that would cause an exodus (financially and / or in human population) from these areas.
 - 5.5.8. It is assumed that no adaptation strategies are taken for the following case studies. Additionally it is assumed that development would continue on a “**business-as-usual**” model to 2030 (and hence development would not be sited with specific consideration of sea level rise impacts, but physical limitations on siting are considered). **A conservative approach is ensured**, however, by using 2030 (and the related development up to that year) as the baseline year for far forward-looking predictions. Given the statistical probability of occurrence of certain sea level rise events, it is considered likely that development would follow the business-as-usual approach up to 2030, resulting in the predicted expansion of infrastructure.
 - 5.5.9. For each of the studies, the impacts were measured and accounted for **as if occurring for the first time** (i.e. the costs and effects of past impacts aren't measured). This is done mostly because of the difficulty gauging the impacts of each study on subsequent scenarios.
 - 5.5.10. Due to the long time spans of sea level rise impacts, it is assumed that immovable property and fixed installations would be the most vulnerable. Where relevant, attention is given to the impacts on health and livelihoods.
 - 5.5.11. The impacts of sea level changes have been conservatively estimated based on mean sea levels: no account was taken of additional variations around the mean other than expected storm surge extremes, unless stated otherwise.
 - 5.5.12. The following findings are listed per impact scenario and then per Namibian coastal settlement, in order of largest / most significant monetary and economic impact to the least (monetary values are expressed in year 2009 value, unless stated otherwise - to allow for fair comparison).
 - 5.5.13. A discount rate of 4-5% was used in line with the expected 11% inflation rate to express all future expenditures in current values for ease of comparison.
 - 5.5.14. It is important to note that the losses (vs. costs) indicated are irrecoverable losses, since the properties in question are (a) ruined and (b) permanently removed from the market. It should be noted also that studies 3(a) and (b) still include a cost component (i.e. damages incurred intermittently, in addition to infrastructure that is lost).
 - 5.5.15. Losses are accounted for as financial impacts assuming that either the lost infrastructure would have to be restored, or would somehow result in insurance claims or book entries as a losses.

5.5.16. The following studies are based on current infrastructure development, extrapolated mathematically for future scenarios. For future projections it should be kept in mind that the bitumen surfaced road infrastructure is likely to expand and replace some current salt roads, which due to uncertainty is not accounted for in the studies' financial models.

5.5.17. It is assumed that the peninsula (sandspit) and hence harbour at Walvisbay would remain intact (preserving the sheltered-environment status) under all scenarios.

5.6. Study 1: Year 2009 extreme sea levels

5.6.1. Summary of scenario

a. Total expected financial impacts, through repairs and replacement of infrastructure, for (*GDP refers only to the named locality's estimated economic activity, in 2009)³:

i.	Walvisbay	N\$ 760 mil	(36% of GDP)
ii.	Swakopmund	N\$ 537 mil	(37% of GDP)
iii.	Lüderitz	N\$ 118 mil	(19% of GDP)
iv.	Hentiesbay	N\$ 85 mil	(56% of GDP)
v.	Total possible financial impact of scenario	N\$ 1.50 bil	

b. The year of occurrence of this study is 2009 or shortly thereafter, and the following coastal towns are evaluated under storm conditions.

c. The damage mentioned in this scenario would be limited by the fact that the storm surges have limited energy to penetrate inland. Walvisbay is low lying for the most part, but with a relatively high beach line over extensive areas, which may mean that the surges may not have enough energy / volume to penetrate as far inland as indicated on the mapping, and thus significantly reduce damages suffered. At Swakopmund, the narrow profile of the ingress zone makes it likely that water damage will reach the projected ingress levels.

d. Please refer to Annex II for the inundation maps for this scenario.

5.6.2. Scenario specifics

a. For all the towns in this study, the sea level is evaluated for expected conditions in the year 2009, during expected extreme storm surge conditions (100 year storm).

b. Walvisbay

i. For this town, in this study, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1.5m (storm level for sheltered environments), to yield the highest storm level.

ii. Approximately 530 properties (4.9% of total) are located such that they might be directly impacted by the current 100-year storm surge scenario. It is assumed though that the storm surges would penetrate less than 0.75km inland (and then

³ Even though the financial impact (cost and loss of infrastructure) is related to an economic indicator (GDP), these impacts should not be confused with economic impact. The financial impacts will certainly be a sub-set of economic impacts: removal of infrastructure needed to conduct business as well as diversion of capital to address the sea level rise impacts, appropriately and inappropriately.

- only in part since the urban sea front is mostly higher than the sea level). Also, the short-lived nature of these occurrences (as opposed to a permanent rise in mean sea levels) would reduce financial loss to lower values.
- iii. The port is expected to suffer little if any impacts under this scenario. The total estimated value of fixed infrastructure at the port in 2009 was ±N\$697mil.
 - iv. The activities at the salt works may be disrupted.
 - v. The northern residential extensions to Walvisbay are small, but consist of very high value properties. The areas will definitely be affected by storm surges, however, the effects will likely follow the same pattern as with Swakopmund. As such no more than 58 properties would directly affected.
- c. Swakopmund
- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 4m (storm level for exposed environments), to yield the average storm level.
 - ii. A total of ±260 properties (2.5% of total) will be directly impacted by current 100-year storm surge scenario. More properties (another estimated 150-250 properties) will be indirectly affected, by infrastructure loss as well as intermittent damage due to localised extremes during storm surges. The possible monetary impact (maintenance cost) below, does not include a margin for the indirectly affected properties. However, the short-lived nature of these occurrences (as opposed to a permanent rise in median sea levels) would limit financial loss to lower values. ±20% of the building conservation area will be directly impacted.
 - iii. The activities at the salt works may be disrupted.
- d. Lüderitz
- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) plus 1.5m (storm level for sheltered environments), to yield the highest storm level.
 - ii. The absence of contour mapping has made detailed analysis of Lüderitz's projected impacts difficult. Supplementary information, however, shows that the impacts on the town and the port would be limited due to the harbour being a sheltered environment and the height above sea level of the town (approximately 20m for a large portion of the town).
 - iii. A total of ±80 properties (2.2% of total) will be lightly impacted by current 100-year storm surge scenario. However, the expected impact would limit financial loss to lower values.
 - iv. It is nor foreseen that the port would suffer major damage during such a storm. More likely damage would be incurred to goods in transit. The total estimated value of fixed infrastructure at the port in 2009 was ±N\$232.4mil.
- e. Hentiesbay

- i. For this town, in this study, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 6m (storm level for very exposed environments), to yield the highest storm level.
- ii. The absence of contour mapping has made detailed analysis of Hentiesbay's projected impacts difficult. Some information was inferred from the Kwazulu Natal storm situations (matching Hentiesbay as an exposed environment) and extrapolated.
- iii. Apparently the dune face area of Hentiesbay (a pure dune shoreline, with some rocky or mixed areas) should be able to withstand such storm conditions to a high degree. If the dune face is aggressively eroded, affecting the first line of houses along the coast, approximately 55 houses (2.1% of total) will be damaged or destroyed. There may also be direct and indirect impacts on properties which are more inland.

5.6.3. Repair / replacement cost: Building infrastructure (private and public)

Possible monetary (year 2009 equivalent) loss, and repair costs (not including a margin for the indirectly affected properties), for:

a. Walvisbay:	<u>N\$ 724 mil</u>
b. Swakopmund:	<u>N\$ 534 mil</u>
c. Lüderitz:	<u>N\$ 117 mil</u>
d. Hentiesbay:	<u>N\$ 85 mil</u>

5.6.4. Repair / replacement cost: Roads, storm water and drainage

Estimated loss and damage to salt and bitumen surfaced roads for:

a. Walvisbay:	<u>N\$ 32 mil</u>
i. An estimated total distance of 8km of salt road as well as 39km tar and concrete paved roads would be permanently lost.	
b. Swakopmund:	<u>N\$ 1.7 mil</u>
i. An estimated additional distance of 1.4km of salt road as well as 1.3km bitumen surfaced and concrete paved roads would be permanently lost.	
c. Lüderitz: No significant impact	
d. Hentiesbay: No significant impact	
e. Inter-urban areas: No significant impact	

5.6.5. Repair / replacement cost: Sewerage and fresh water connections

Estimated total loss and damage to sewerage and fresh water infrastructure in year 2009 value, discounting operation and maintenance costs to the 2030 date will be, for:

a. Walvisbay:	<u>N\$ 1.8 mil</u>
b. Swakopmund:	<u>N\$ 0.4 mil</u>

- c. Lüderitz: N\$ 0.1 mil
- d. Hentiesbay: N\$ 0.1 mil

5.6.6. **Repair / replacement cost: Electricity distribution**

Estimated total loss and damage to electrical infrastructure, by 2030, in year 2009 value, discounting operation and maintenance costs will be, for:

- a. Walvisbay: N\$ 2.2 mil
- b. Swakopmund: N\$ 1.1 mil
- c. Lüderitz: N\$ 0.3 mil
- d. Hentiesbay: N\$ 0.2 mil
- e. Inter-urban areas
 - i. No significant impacts are predicted for current and near-future electrical infrastructure planning.

5.6.7. **Impacts on water resources**

- a. Impacts on fresh water aquifers are discussed in the fourth study.

5.7. **Study 2: Sea level rise projected for the near future (2030)**

5.7.1. Summary of scenario

- a. Total expected financial impacts to date, through repairs and replacement of infrastructure, but excluding maintenance, for (*GDP refers only to the named locality's estimated 2030 economic activity)⁴:

i.	Walvisbay	N\$ 1.4 bil	(32% of GDP)
ii.	Swakopmund	N\$ 656 mil	(22% of GDP)
iii.	Lüderitz	N\$ 215 mil	(17% of GDP)
iv.	Hentiesbay	N\$ 156 mil	(50% of GDP)
v.	Inter-urban areas	N\$ -	
vi.	Total possible financial impact of scenario	N\$ 2.42 bil	

- b. The year of occurrence of this study is approximately 2030, and the following coastal towns are evaluated under storm conditions expected in that year.
- c. The damage mentioned in this scenario would be limited by the fact that the storm surges have limited energy to penetrate inland. Walvisbay is low lying for the most part, but with a relatively high beach line over extensive areas, which may mean that the surges may not have enough energy / volume to penetrate as far inland as indicated on the mapping, and thus significantly reduce damages suffered. At Swakopmund, the narrow profile of the ingress zone makes it likely that water damage will reach the projected ingress levels.

⁴ Even though the financial impact (cost and loss of infrastructure) is related to an economic indicator (GDP), these impacts should not be confused with economic impact. The financial impacts will certainly be a sub-set of economic impacts: removal of infrastructure needed to conduct business as well as diversion of capital to address the sea level rise impacts, appropriately and inappropriately.

d. Please refer to Annex II for the inundation maps for this scenario.

5.7.2. Scenario specifics

- a. For all the towns in this study, the sea level is evaluated for expected conditions in the year 2030, during expected extreme storm surge conditions.
- b. Walvisbay
 - i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1.5m (storm level for sheltered environments), to yield the highest storm level – *which in this scenario could become a yearly occurrence by 2030*.
 - ii. A total of ±985 properties (estimated 4.9% of the total 20,303 at that time) could be impacted in the 2030 scenario. It is assumed though that the storm surges would penetrate less than 1km inland (and then only in part since the urban sea front is mostly higher than the sea level). It is hard to determine how much the financial costs would be reduced (because of the temporary nature of storms) from this costs estimate, since the unmitigated impacts could, due to climatic changes, be an annual occurrence under this scenario, for this locality.
 - iii. By 2030, the port authority NamPort may have already implemented an expansion of the Walvisbay port to approximately double its current size. It is nor foreseen that the port would suffer major damage during such a storm. More likely, damage would be incurred to ships and goods in transit, and the extensive disruption of port activities.
 - iv. The salt works will be extensively impacted.
 - v. In 2030 these extensions would have expanded to about 821 properties which would mean that approximately 95 properties would be directly impacted in these areas.
- c. Swakopmund
 - i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 4m (storm level for exposed environments), to yield the highest storm level in 2030.
 - ii. A total of ±320 properties (1.6% of total at that time) will be directly impacted in the 2030 scenario. More properties (another estimated 300-350 properties) will be indirectly affected, by infrastructure loss as well as intermittent damage due to localised extremes during storm surges. The possible monetary impact (maintenance cost) below, does not include a margin for the indirectly affected properties. It is difficult to say whether the financial costs would be reduced from the above loss estimate, since the unmitigated impacts would, due to climatic changes, be a regular (though not annually) occurrence under this scenario.
 - iii. The salt works will be extensively impacted.
- d. Lüderitz

- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) plus 1.5m (storm level for sheltered environments), to yield the highest storm level in 2030.
 - ii. The absence of contour mapping has made detailed analysis of Lüderitz's projected impacts difficult. Supplementary information, however, shows that the impacts on the town and the port would be limited due to the harbour being a sheltered environment and the height above sea level of the town (approximately 20m for a large portion of the town).
 - iii. A total of ±149 properties (2.2% of total) will be directly impacted in the 2030 storm surge scenario. However, the nature of the expected impact would limit financial loss, below, to lower values.
 - iv. Operations at the port will very likely be impacted.
- e. Hentiesbay
- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) plus 6m (storm level for very exposed environments), to yield the highest storm level in 2030.
 - ii. The absence of contour mapping has made detailed analysis of Hentiesbay's projected impacts difficult. Some information was inferred from the Kwazulu Natal storm situations (matching Hentiesbay as an exposed environment) and extrapolated.
 - iii. A total of approximately 102 properties (2.1% of the total 4,898 at that time) will be directly impacted, though more often. There may also be direct and indirect impacts on properties which are more inland.

5.7.3. Repair / replacement cost: Building infrastructure (private and public)

Possible monetary (year 2009 equivalent) loss, and repair costs (not including a margin for the indirectly affected properties), for:

- | | |
|----------------|--------------------|
| a. Walvisbay: | <u>N\$ 1.3 bil</u> |
| b. Swakopmund: | <u>N\$ 652 mil</u> |
| c. Lüderitz: | <u>N\$ 214 mil</u> |
| d. Hentiesbay: | <u>N\$ 155 mil</u> |

5.7.4. Repair / replacement cost: Roads, storm water and drainage

Estimated loss and damage to salt and bitumen surfaced roads for:

- | | |
|---|-------------------|
| a. Walvisbay: | <u>N\$ 58 mil</u> |
| i. An estimated total distance of 63km of salt road as well as 24km tar and concrete paved roads would be permanently lost. | |
| b. Swakopmund: | <u>N\$ 2 mil</u> |

- i. An estimated additional distance of 1.7km of salt road as well as 1.6km bitumen surfaced and concrete paved roads would be permanently lost.
- c. Lüderitz: No significant impact
- d. Hentiesbay: No significant impact
- e. Inter-urban areas: No significant impact

5.7.5. **Repair / replacement cost: Sewerage and fresh water connections**

Estimated total loss and damage to sewerage and fresh water infrastructure in year 2009 value, discounting operation and maintenance costs to the 2030 date will be, for:

a. Walvisbay:	<u>N\$ 3 mil</u>
b. Swakopmund:	<u>N\$ 0.4 mil</u>
c. Lüderitz:	<u>N\$ 0.2 mil</u>
d. Hentiesbay:	<u>N\$ 0.2 mil</u>

5.7.6. **Repair / replacement cost: Electricity distribution**

Estimated total loss and damage to electrical infrastructure, by 2030, in year 2009 value, discounting operation and maintenance costs will be, for:

a. Walvisbay:	<u>N\$ 4 mil</u>
b. Swakopmund:	<u>N\$ 1 mil</u>
c. Lüderitz:	<u>N\$ 0.6 mil</u>
d. Hentiesbay:	<u>N\$ 0.4 mil</u>
e. <u>Inter-urban areas</u>	

- i. No significant impacts are predicted for current and near-future electrical infrastructure planning.

5.7.7. **Impacts on water resources**

- a. Impacts on fresh water aquifers are discussed in the fourth study.

5.8. **Future scenarios under significant atmospheric GHG concentration increases**

5.8.1. Summary

The conditions projected for the following three scenarios – 3(a), (b) and (c) – would develop over an uncertain time span. In line with IPCC practice, these scenarios are therefore not projected to specific dates, but rather to specific stabilisation levels of atmospheric GHGs. The impacts listed therefore are based on the 2030 level of development to present a conservative estimate based on a known point in time.

- 5.8.2. For the future scenarios, the financial impacts of sea level rise is shown in year 2009 monetary values, discounting operation and maintenance costs (for public infrastructure).

- 5.8.3. The absence of contour mapping has made detailed analysis of Lüderitz's projected impacts difficult. Supplementary information, however, shows that the impacts on the

town and the port would be limited due to the harbour being a sheltered environment and the height above sea level of the town (approximately 20m for a large portion of the town).

- 5.8.4. The impacts on the regional electrical infrastructure are limited under these scenarios, since the Walmund substation, and connected Kuisebmond substation near Walvisbay, are located well inland. The distribution reticulation to and from this substation is also safely inland.
- 5.8.5. ErongoRED has stated that no new bulk infrastructure would be constructed near the coastline before 2019. It is assumed however that, due to the corrosive atmosphere near the coast, that no such infrastructure would be constructed within an area that could be inundated.

5.9. Study 3(a): Sea level rise scenario

5.9.1. Summary of scenario

- a. Total expected financial impacts, excluding maintenance, for (*GDP refers only to the named locality's estimated 2030 economic activity)⁵:

i.	Walvisbay	N\$ 22.7 bil	(515% of GDP)
ii.	Swakopmund	N\$ 806 mil	(27% of GDP)
iii.	Lüderitz	N\$ 249 mil	(20% of GDP)
iv.	Hentiesbay	N\$ 176 mil	(56% of GDP)
v.	Inter-urban areas	N\$ 3 mil	
vi.	Total possible financial impact of scenario	N\$ 23.9 bil	

- b. The year of occurrence of this study is projected to 2030, and the following coastal towns are evaluated under storm conditions, as if occurring during that year.
- c. Please refer to Annex II for the inundation maps for this scenario.

5.9.2. Scenario specifics

- a. For all the towns in this study, the sea level is evaluated where atmospheric CO₂ concentration has reached 450ppm, during expected storm surge conditions.
- b. Walvisbay
- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1m (mean sea level rise) *plus* 1.5m (storm level for sheltered environments).
 - ii. Discounting the impact of the destruction or breach of the peninsula (sandspit), this scenario results in a large portion of Walvisbay town being inundated. A total of ±16,968 properties (including the properties mentioned in previous scenarios; 83% of the total 20,303 at that time) will be directly impacted. Most

⁵ Even though the financial impact (cost and loss of infrastructure) is related to an economic indicator (GDP), these impacts should not be confused with economic impact. The financial impacts will certainly be a sub-set of economic impacts: removal of infrastructure needed to conduct business as well as diversion of capital to address the sea level rise impacts, appropriately and inappropriately. Impacts are valued as if happening for the first time.

- of the remaining properties would likely be affected by localised extremes or infrastructure damage.
- iii. Operations at the port will very likely be impacted unless adapted.
 - iv. The salt works will be extensively impacted and possibly destroyed.
 - v. Long Beach and Dolphin Beach: Impacts the same as in Swakopmund can be expected. Approximately 100 properties would be directly affected / lost.
- c. Swakopmund
- i. For this town the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1m (mean sea level rise) *plus* 4m (storm level for exposed environments).
 - ii. A total of approximately 400 properties (including the properties mentioned in previous scenarios; 2.1% of total at that time) will be directly impacted. More properties (another estimated 400-500 properties) may be indirectly affected, by infrastructure loss as well as intermittent damage due to storms variations. $\pm 25\%$ of the building conservation area will be directly impacted.
 - iii. The salt works will be heavily impacted and possibly destroyed.
- d. Lüderitz
- i. For this town, in this study, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1m (mean sea level rise) *plus* 1.5m (storm level for sheltered environments).
 - ii. A total estimated 164 properties (including the properties mentioned in previous scenarios; 2.4% of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms variations.
 - iii. Operations at the port will very likely be impacted unless adapted.
- e. Hentiesbay
- i. For this town, in this study, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 1m (mean sea level rise) *plus* 6m (storm level for very exposed environments).
 - ii. A total estimated 113 properties (including the properties mentioned in previous scenarios; 2.3% of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms variations.

5.9.3. Replacement cost: Building infrastructure (private and public)

Possible monetary (year 2009 equivalent) loss, and repair costs (not including a margin for the indirectly affected properties), for:

- a. Walvisbay: N\$ 1.3 bil
 - i. Walvisbay port: N\$ 100 mil
 - ii. There will be some impact at the port. Loss of port infrastructure is not likely to be extensive, but goods in

transit and ships would definitely be affected. Operations at the port will be significantly impacted.

- b. Swakopmund: N\$ 652 mil
- c. Lüderitz: N\$ 214 mil
 - i. Lüderitz port: N\$ 50 mil
 - ii. There will be some impact at the port. Loss of port infrastructure is not likely to be extensive, but goods in transit and ships would definitely be affected. Operations at the port will be significantly impacted.
- d. Hentiesbay: N\$ 155 mil

5.9.4. **Replacement cost: Roads, storm water and drainage**

Estimated loss on salt and bitumen surfaced roads for:

- a. Walvisbay: N\$ 58 mil
 - i. An estimated total distance of 87km of salt road as well as 226km tar and concrete paved roads would be permanently lost.
- b. Swakopmund: N\$ 2 mil
 - i. An estimated additional distance of 1.6km of salt road as well as 1.7km bitumen surfaced and concrete paved roads would be permanently lost.
- c. Lüderitz: No significant impact
- d. Hentiesbay: No significant impact
- e. Inter-urban areas: N\$ 3 mil
 - i. It is uncertain whether the road to Hentiesbay would be upgraded to a bitumen road. The above assumes this is not done, and that no further development of the Swakopmund-Walvisbay road is done.

5.9.5. **Replacement cost: Sewerage and fresh water connections**

Estimated total loss of sewerage and fresh water infrastructure in year 2009 value, discounting operation and maintenance costs to the 2030 date will be, for:

- a. Walvisbay: N\$ 3 mil
- b. Swakopmund: N\$ 0.4 mil
- c. Lüderitz: N\$ 0.2 mil
- d. Hentiesbay: N\$ 0.2 mil

5.9.6. **Replacement cost: Electricity distribution**

Estimated total loss and damage to electrical infrastructure, by 2030, in year 2009 value, discounting operation and maintenance costs will be, for:

- a. Walvisbay: N\$ 4 mil

- | | |
|---|--------------------|
| b. Swakopmund: | <u>N\$ 1 mil</u> |
| c. Lüderitz: | <u>N\$ 0.6 mil</u> |
| d. Hentiesbay: | <u>N\$ 0.4 mil</u> |
| e. <u>Inter-urban areas</u> | |
| i. No significant impacts are predicted for current and near-future electrical infrastructure planning. Increased attack on electrical infrastructure may be a possibility by the increase of corrosive elements in the atmosphere due to the higher sea temperatures and deeper penetration of the sea inland. | |
| ii. In the case where wind power parks are developed along the coast (as is currently under investigation), it may be that when incorrectly sited, these wind turbines could suffer extensive damage due to corrosion and erosion if not relocated at great expense and effort. | |

5.9.7. Impacts on water resources

- a. Impacts on fresh water aquifers are discussed in the fourth study.
- b. The desalination plant at Wlotzkasbaken might be at risk, but no flooding data is available. This scheme supplies the Trekkoppie Uranium mine.
- c. The proposed desalination plant of NamWater, near Swakopmund may be at risk, depending on the final design.

5.10. Study 3(b): Sea level rise scenario

5.10.1. Summary of scenario

- a. Total expected financial impacts, excluding maintenance, for (*GDP refers only to the named locality's estimated 2030 economic activity)⁶:

i. Walvisbay	N\$ 26.1 bil	(595% of GDP)
ii. Swakopmund	N\$ 979 mil	(33% of GDP)
iii. Lüderitz	N\$ 297 mil	(23% of GDP)
iv. Hentiesbay	N\$ 301 mil	(96% of GDP)
v. Inter-urban areas	N\$ 7 mil	
vi. Total possible financial impact of scenario	N\$ 27.7 bil	

- b. The year of occurrence of this study is projected to 2030, and the following coastal towns are evaluated under storm conditions, as if occurring during that year.
- c. Please refer to Annex II for the inundation maps for this scenario.

⁶ Even though the financial impact (cost and loss of infrastructure) is related to an economic indicator (GDP), these impacts should not be confused with economic impact. The financial impacts will certainly be a sub-set of economic impacts: removal of infrastructure needed to conduct business as well as diversion of capital to address the sea level rise impacts, appropriately and inappropriately. Impacts are valued as if happening for the first time.

5.10.2. Scenario specifics

- a. For all the towns in this study, the sea level is evaluated where atmospheric CO₂ concentration has reached 550ppm, during expected storm surge conditions.
- b. Walvisbay
 - i. For this town, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 2m (mean sea level rise) *plus* 1.5m (storm level for sheltered environments).
 - ii. Discounting the impact of the destruction or breach of the peninsula (sandspit), this scenario still results in virtually the entire Walvisbay town being inundated. An estimated total of 19,636 properties (97% of the total 20,303 at that time) could be directly impacted. Most of the remaining properties would likely be affected by localised extremes.
 - iii. The port will very likely be destroyed or extensively damaged unless adapted.
 - iv. The salt works will be destroyed.
 - v. Long Beach and Dolphin Beach: Impacts the same as in Swakopmund can be expected. Approximately 110 properties would be directly affected / lost.
- c. Swakopmund
 - i. For this town, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 2m (mean sea level rise) *plus* 4m (storm level for exposed environments).
 - ii. A total of 500 properties (including the properties previously mentioned; 2.6% of total at that time) will be directly impacted. More properties (another estimated 500-550 properties) may be indirectly affected, by infrastructure loss as well as intermittent damage due to storms. $\pm 38\%$ of the building conservation area will be directly impacted.
 - iii. The salt works will be destroyed.
- d. Lüderitz
 - i. For this town, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 2m (mean sea level rise) *plus* 1.5m (storm level for sheltered environments).
 - ii. A total estimated 196 properties (including the properties mentioned in previous scenarios; 2.9% of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms variations.
 - iii. The port will very likely be destroyed or extensively damaged unless adapted.
- e. Hentiesbay
 - i. For this town, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 2m (mean sea level rise) *plus* 6m (storm level for very exposed environments).

- ii. A total estimated 358 properties (including the properties mentioned in previous scenarios; 5.3% of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms variations.

5.10.3. Replacement cost: Building infrastructure (private and public)

Possible monetary (year 2009 equivalent) loss, and repair costs (not including a margin for the indirectly affected properties), for:

- a. Walvisbay: N\$ 25.3 bil
 - i. Walvisbay port (all infrastructure lost): N\$ 1.4 bil
 - ii. The damage / loss of harbour infrastructure at that time (excluding cargo in transit) is the approximate value of fixed infrastructure at the port in 2009.
- b. Swakopmund: N\$ 960 mil
- c. Lüderitz: N\$ 280 mil
 - i. Lüderitz port (all infrastructure lost): N\$ 232 mil
 - ii. The damage / loss of harbour infrastructure at that time (excluding cargo in transit) is the approximate value of fixed infrastructure at the port in 2009.
- d. Hentiesbay: N\$ 292 mil

5.10.4. Replacement cost: Roads, storm water and drainage

Estimated loss on salt and bitumen surfaced roads for:

- a. Walvisbay: N\$ 271 mil
 - i. An estimated total distance of 90km of salt road as well as 223km tar and concrete paved roads would be permanently lost.
- b. Swakopmund: N\$ 3.4 mil
 - i. An estimated additional distance of 2.3km of salt road as well as 2.3km bitumen surfaced and concrete paved roads would be permanently lost.
- c. Lüderitz: N\$ 10.6 mil
 - i. An estimated total distance of 11.2km bitumen surfaced and concrete paved roads would be permanently lost.
- d. Hentiesbay: N\$ 4 mil
 - i. An estimated total distance of 5km salt surfaced roads would be permanently lost.
- e. Inter-urban areas: N\$ 7 mil
 - i. It is uncertain whether the road to Hentiesbay would be upgraded to a bitumen road. The above assumes this is not

done, and that no further development of the Swakopmund-Walvisbay road is done.

5.10.5. Replacement cost: Sewerage and fresh water connections

Estimated total loss of sewerage and fresh water infrastructure in year 2009 value, discounting operation and maintenance costs to the 2030 date will be, for:

a. Walvisbay:	<u>N\$ 261 mil</u>
b. Swakopmund:	<u>N\$ 7 mil</u>
c. Lüderitz:	<u>N\$ 3 mil</u>
d. Hentiesbay:	<u>N\$ 3 mil</u>

5.10.6. Replacement cost: Electricity distribution

Estimated total loss and damage to electrical infrastructure, by 2030, in year 2009 value, discounting operation and maintenance costs will be, for:

a. Walvisbay:	<u>N\$ 324 mil</u>
b. Swakopmund:	<u>N\$ 8 mil</u>
c. Lüderitz:	<u>N\$ 3 mil</u>
d. Hentiesbay:	<u>N\$ 3 mil</u>
e. <u>Inter-urban areas</u>	

- i. No significant impacts are predicted for current and near-future electrical infrastructure planning. Increased attack on electrical infrastructure may be a possibility by the increase of corrosive elements in the atmosphere due to the higher sea temperatures and deeper penetration of the sea inland.
- ii. In the case where wind power parks are developed along the coast (as is currently under investigation), it may be that when incorrectly sited, these wind turbines could suffer extensive damage due to corrosion and erosion if not relocated at great expense and effort.

5.10.7. Impacts on water resources

- a. Impacts on fresh water aquifers are discussed in the fourth study.
- b. The desalination plant at Wlotzkasbaken might be at risk, but no flooding data is available. This scheme supplies the Trekkoppie Uranium mine.
- c. The proposed desalination plant of Namwater, near Swakopmund may be at risk, depending on the final design.

5.11. Study 3(c): Sea level rise scenario after collapse of polar ice caps

5.11.1. Summary of scenario

- a. Total expected financial impacts, excluding maintenance, for (*GDP refers only to the named locality's estimated 2030 economic activity)⁷:

i.	Walvisbay	N\$ 28.4 bil	(615% of GDP)
ii.	Swakopmund	N\$ 2.86 bil	(95% of GDP)
iii.	Lüderitz	N\$ 436 mil	(34% of GDP)
iv.	Hentiesbay	N\$ 445 mil	(141% of GDP)
v.	Inter-urban areas	N\$ 29 mil	
vi.	Total possible financial impact of scenario	N\$ 32.2 bil	

- b. The year of occurrence of this study is projected to 2030, and the following coastal towns are evaluated as if this situation occurred during that year.
- c. Please refer to Annex II for the inundation maps for this scenario.

5.11.2. Scenario specifics

- a. For all the towns, in this study, the sea level is evaluated at the year 2009 mean sea level (LLD) *plus* 10m (mean sea level rise); where atmospheric CO₂ concentration has reached 750ppm.
- b. Walvisbay
- i. This scenario results in the entire Walvisbay town being inundated. All estimated 20,303 properties will be lost.
 - ii. The port will be completely destroyed unless adapted.
 - iii. The salt works will be destroyed.
 - iv. Long Beach and Dolphin Beach: Impacts the same as in Swakopmund can be expected. Approximately 115 properties would be directly affected / lost.
- c. Swakopmund
- i. A total of ±1500 properties (including the properties mentioned in previous scenarios; 7.8% of total at that time) will be directly. The foregoing figure does not take into account storm variations. More properties may be indirectly affected, by infrastructure loss as well as intermittent damage due to storms. ±45% of the building conservation area will be directly impacted.
 - ii. The salt works will be destroyed.
- d. Lüderitz

⁷ Even though the financial impact (cost and loss of infrastructure) is related to an economic indicator (GDP), these impacts should not be confused with economic impact. The financial impacts will certainly be a sub-set of economic impacts: removal of infrastructure needed to conduct business as well as diversion of capital to address the sea level rise impacts, appropriately and inappropriately. Impacts are valued as if happening for the first time.

- i. A total estimated 295 properties (including the properties mentioned in previous scenarios; $\pm 4.4\%$ of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms.
- ii. The port will be completely destroyed unless adapted.
- e. Hentiesbay
 - i. A total estimated 537 properties (including the properties mentioned in previous scenarios; 6% of total at that time) will be directly impacted. More properties may be indirectly affected by infrastructure loss as well as intermittent damage due to storms.

5.11.3. Replacement cost: Building infrastructure (private and public)

Possible monetary (year 2009 equivalent) loss, and repair costs (not including a margin for the indirectly affected properties), for:

- a. Walvisbay (all infrastructure lost): N\$ 26.1 bil
 - i. Walvisbay port (all infrastructure lost): N\$ 1.4 bil
 - ii. The loss of harbour infrastructure at that time (excluding cargo in transit) is the approximate value of fixed infrastructure at the port in 2009.
- b. Swakopmund: N\$ 2.8 bil
- c. Lüderitz: N\$ 414 mil
 - i. Lüderitz port (all infrastructure lost): N\$ 232 mil
 - ii. The damage / loss of harbour infrastructure at that time (excluding cargo in transit) is the approximate value of fixed infrastructure at the port in 2009.
- d. Hentiesbay: N\$ 432 mil

5.11.4. Replacement cost: Roads, storm water and drainage

Estimated loss on salt and bitumen surfaced roads for:

- a. Walvisbay: N\$ 291 mil
 - i. An estimated total distance of 97km of salt road as well as 251km tar and concrete paved roads would be permanently lost.
- b. Swakopmund: N\$ 4.9 mil
 - i. An estimated additional distance of 6.2km of salt road as well as 2.8km bitumen surfaced and concrete paved roads would be permanently lost.
- c. Lüderitz: N\$ 7.4 mil
 - i. An estimated total distance of 13km bitumen surfaced and concrete paved roads would be permanently lost.

- d. Hentiesbay: N\$ 4 mil
 - i. An estimated total distance of 7.29km salt surfaced roads would be permanently lost.
- e. Inter-urban areas: N\$ 28.6 mil
 - i. It is uncertain whether the road to Hentiesbay would be upgraded to a bitumen road. The above assumes this is not done, and that no further development of the Swakopmund-Walvisbay road is done.

5.11.5. Replacement cost: Sewerage and fresh water connections

Estimated total loss of sewerage and fresh water infrastructure in year 2009 value, discounting operation and maintenance costs to the 2030 date will be, for:

- a. Walvisbay: N\$ 270 mil
- b. Swakopmund: N\$ 20 mil
- c. Lüderitz: N\$ 4.5 mil
- d. Hentiesbay: N\$ 4.5 mil

5.11.6. Replacement cost: Electricity distribution

Estimated total loss and damage to electrical infrastructure, by 2030, in year 2009 value, discounting operation and maintenance costs will be, for:

- a. Walvisbay: N\$ 335 mil
- b. Swakopmund: N\$ 24.8 mil
- c. Lüderitz: N\$ 4.9 mil
- d. Hentiesbay: N\$ 4.9 mil
- e. Inter-urban areas
 - i. No significant impacts are predicted for current and near-future electrical infrastructure planning. Increased attack on electrical infrastructure may be a possibility by the increase of corrosive elements in the atmosphere due to the higher sea temperatures and deeper penetration of the sea inland.
 - ii. In the case where wind power parks are developed along the coast (as is currently under investigation), it may be that when incorrectly sited, these wind turbines could suffer extensive damage due to corrosion and erosion if not relocated at great expense and effort.

5.11.7. Impacts on water resources

- a. Impacts on fresh water aquifers are discussed in the fourth study.
- b. The desalination plant at Wlotzkasbaken might be at serious risk, but no flooding data is available. This scheme supplies the Trekkoppie Uranium mine.

- c. The proposed desalination plant of NamWater, near Swakopmund may be at serious risk, depending on the final design.

5.12. Study 4: Other impacts of sea level rise and notes

5.12.1. General

- a. In terms of projecting the value of future impacts and without consideration to the foregoing, the economic value of the impact is likely to double in magnitude every five to six years.
- b. No account was taken in the financial modelling of possible large scale industrial activities which would increase the growth figures of human settlements, or the irrecoverable destruction of fishing resources which would negatively impact economic growth.
- c. Account was also not taken of the variable property market, which tended to show non-linear growth spurts, and rarely any contractions.

5.12.2. Walvisbay

a. Fresh water availability

The lower Kuiseb River aquifers consist of the aquifers located in the Kuiseb River, from the mouth of the Aussenanis River, downstream to the coast, over a distance of approximately 50km. A large part (92%) of the lower compartment (Rooibank B, including Dorob) is in hydraulic continuity with saline water. This is the portion of the compartment that is located below current sea level. The Rooibank B portion of the aquifer is currently only utilised to a limited extent due to sea level intrusion and recharge issues. Impact from sea level rise can be expected, as the aquifer is currently already sensitive to seawater intrusion. The level of impact can be predicted through the compilation of a groundwater model. Impact on the other aquifer compartments is less likely, as they are located above the current sea level.

Impact on this scheme will have an impact on the whole Central Namib Water Supply scheme, stretching as far as Rössing Uranium and other Mines in the area.

- b. It should be noted that the sandspit has been designated as highly vulnerable, and its collapse has serious and extensive implications for the harbour area. At the same time, the sand deposition along the peninsula due to the Benguela sea current is quite extensive and could replenish the sandspit.
- c. The property types affected would be residential (constituting the majority of the urban space), commercial and industrial in nature as well as public buildings and public open space.
- d. The further development of beachfront property is very likely. The area between Walvisbay and Dolphin Beach is low lying could possibly be subject to the same level of impacts as the town proper.

- e. Bitumen surfaced road infrastructure is likely to expand and replace some current salt roads (this is not accounted for in this analysis).

- f. Loss or disruption of the port activities

The damage or destruction of the port would incur a severe blow to the entire Namibian economy, by its direct impact on the importation of goods and fuels and on the local fishing fleets. The port is directly and indirectly the largest creator of employment in the Walvisbay economy. Of chief concern though, is its function in the importation of liquid fossil fuels on which the Namibian economy is critically dependant.

- g. Loss to aquaculture and fisheries sectors

Walvisbay supports relatively large oyster farming operations, as well as the fishing industry through the local port. The oyster farming operations would be heavily impacted by sea temperature or chemistry changes. It can be expected that increased atmospheric CO₂ would increase the acidity of sea water which in turn could reduce fish populations and thus impact the fishing industry also. Changes in the sea water temperature and composition was not investigated with reference to its impacts on aquaculture.

- h. Loss to other economic sectors

The Walvisbay EPZ appears to be clear of the impacts of sea level rise, other than of secondary or knock-on effects (i.e. impeded availability of services and human resources). Most all industrial and commercial activities in the town itself would be heavily impacted under all scenarios. Widespread damage should be expected under severe storm conditions, and a total loss under the long term scenarios, but for a handful of operations. Disruptions would therefore impact a large percentage of Walvisbay's economic activities.

In the case of Walvisbay, the fundamental need for a port service would be a strong counterbalance to any negative investment sentiment. It is assumed that Namibia's Government would be willing to invest in the protection of or, preferably, assist in the long term upgrading (/relocation) of the port to cope with the sea level changes.

Also, the attractiveness and expanse of the local environment would remain mostly intact (due simply to the physical size of the areas involved), creating positive investment sentiment.

- i. Loss to the public sector

There several Government and local government offices would be impacted under all the scenarios, as well as private and public healthcare facilities and schools.

- j. Loss to the tourism sector

Walvisbay's economy is not heavily dependent on tourism (though there is a small but lively tourism industry), or sport and recreational fishing.

The extensive impacts of sea level rise as seen in the foregoing scenarios indicate that Walvisbay should not prioritise these industries in its drive to adapt to sea level rise.

Obviously, tourists and holiday makers seeking to invest in property at the coast around Walvisbay would be much more cautious, even though the high value, high growth northern extensions appear to be mostly clear of harm's way.

5.12.3. Swakopmund

a. Fresh water availability

Freshwater is sourced from the Kuiseb Scheme (see under Walvisbay) and from the Omdel Scheme (see under Henties Bay). Groundwater is not currently utilised from the Swakop River, in the area deemed to be impacted. Availability of water to Swakopmund is currently directly at the same risk as that of Henties Bay and Walvisbay, as they share water resources.

- b. The permanent loss of the beaches should not be discounted since these play an important role in tourism. Significant sea-level rise would necessitate the removal of fixed structures and infrastructure to [re]create open beach areas. The sea would by erosion achieve the same results over a longer time span.
- c. The bulk of the affected properties are residential in nature, but public open space will also be affected. A small number of businesses (light commerce) and public buildings would also be adversely affected.
- d. The future impact of sea level rise should be carefully considered in the light of the national growth figures, since further development of beachfront property (up to 15-20m above normal sea level) may not match the growth of the town, given the space limitations. Swakopmund town has already developed to close proximity of its northern and southern town boundaries which will limit beachfront expansion, where the greatest impact is expected.
- e. No account was taken for the opening of new uranium mines or other possible very large scale industrial activities which would further boost the figure.
- f. Loss to the public sector

The Swakopmund museum and aquarium as well as several Government offices would be impacted under all the scenarios.

g. Loss to the tourism sector

It was not foreseen that the sea level rise would cause a situation that would definitely cause great impact – positive or negative – to the normal tourism sector. Obviously, tourists seeking to invest in property at the coast would have to be more cautious, but there should be no reason for this coastal town to halt its economic growth. The time scales over which these changes occur would allow for adequate planning and adaptation.

It is unlikely that sport and recreational fishing (whether formal or informal) would be impacted, other than by the impacts on fish populations due to sea characteristics changes.

h. Loss to aquaculture and fisheries sectors

Swakopmund does not support fishing or aquaculture on large scale. Oyster and abalone farming are supported on small scales. The only impact on the oyster farming due to sea level rise would be limited destruction of some of the infrastructure. The onshore abalone farming would suffer higher losses due to its fixed infrastructure requirement. Both activities yield high value products, whereby the loss in productivity / opportunity costs are likely to outweigh infrastructure costs in the longer term.

Changes in the sea water temperature and composition was not investigated with reference to its impacts on aquaculture.

i. Loss to other economic sectors

The same arguments as above hold for most industrial and commercial development in Swakopmund. There would be relatively little impact on the day-to-day activities in largest parts of the town. The salt processing plant is a notable exception; which could suffer extensive loss or incur significant cost in relocating, given the conditions in Scenario 3 (refer to Annex II for detailed mapping). Physical conditions beyond the 15-20m contours appear conducive to continuation of business, but significant earth works would still be needed (within current Swakopmund town lands).

Inland mining activities and the attractiveness and expanse of the local environment which would remain mostly intact (due simply to the physical size of the areas involved) would probably counteract negative investment sentiment, apart from beachfront properties.

5.12.4. Lüderitz

a. Fresh water availability

Freshwater is sourced from the Koichab Scheme, approximately 100km inland. This scheme is not considered to be at risk from sea level rise as per the values predicted in this report.

b. Loss or disruption of the port activities

The damage or destruction of the port would significantly impact the entire Namibian economy, by its impact on the importation and exportation of goods and fuels and on the local fishing fleets. The port is directly and indirectly creates a large percentage employment in the local economy.

c. Loss to aquaculture and fisheries sectors

Lüderitz the fishing and crayfish industry through the local port. It can be expected that increased atmospheric CO₂ would increase the acidity of sea water which in turn could reduce fish populations and thus impact the fishing industry also. Changes in the sea water temperature and composition was not investigated with reference to its impacts on aquaculture.

d. Loss to other economic sectors

Most of the industrial and some commercial activities in the town itself would be heavily impacted under especially the later scenarios. Widespread damage should be

expected under severe storm conditions, and a total loss under the long term scenarios for those closest to the harbour. The port itself may face eventual destruction, but the harbour should remain mostly intact and offer good opportunity for redevelopment.

The attractiveness of the local environment would remain mostly intact, which should hopefully counteract negative investment sentiment.

e. Loss to the tourism sector

The tourism sector in this area should remain robust despite extreme climatic changes.

5.12.5. Hentiesbay

a. Fresh water availability

Freshwater is sourced from the Omdel Scheme as well as from Municipal boreholes located in the Omaruru River, close to the Atlantic Ocean. The Omdel Scheme stretches from the Atlantic Ocean, along the Omaruru River, for more than 35km inland. The first 10km of the aquifer is partially located below sea level and would thus be at risk of seawater intrusion. By managing the freshwater head in the aquifer, the seawater intrusion can however be managed and is currently managed as such. This however limits the amount of water that can be extracted from the aquifer. It is expected that the Municipal boreholes located in Henties Bay would be at risk from sea level rise. This can however be mitigated through a lowering of abstraction from upstream, to ensure sufficient freshwater head is available to control the seawater intrusion. Alternatively the town can rely solely on supply from upstream boreholes, operated by Namwater.

Impact on this scheme will have an impact on the whole Central Namib Water Supply scheme, stretching as far as Rössing Uranium and other Mines in the area.

b. Loss to the public sector

The governmental research station should be unaffected by the impacts of sea level changes, as with the local government buildings.

c. Loss to the tourism sector

It is not foreseen that the sea level rise would cause a situation that would definitely cause great impact – positive or negative – to the normal tourism sector. Obviously, tourists seeking to invest in property at the coast would have to be more cautious, but there should be no reason for this coastal town to halt its economic growth. The time scales over which these changes occur would allow for adequate planning and adaptation.

It is unlikely that sport and recreational fishing (whether formal or informal) would be impacted, other than by the impacts on fish populations due to sea characteristics changes.

d. Loss to other economic sectors

The same arguments as above hold for most industrial and commercial development in Hentiesbay: such activities can continue, since the zoned areas are well inland.

The expanse of the local environment which would remain mostly intact (due simply to the physical size of the areas involved) would probably counteract negative investment sentiment, apart from the beachfront properties.

5.12.6. Inter-urban areas

a. Water

- i. No other currently exploited aquifers, than those mentioned above, are considered to be at risk.
- ii. The desalination plant at Wlotzkasbaken might be at risk, but no flooding data is available. This scheme supply the Trekkoppie Uranium mine.
- iii. The proposed desalination plant of Namwater, near Swakop is not considered to be at risk, although the seawater intake might be.

b. Roads

Walvisbay and Swakopmund are linked by a high quality bitumen surfaced road, over 31km long. The Dolphin & Long Beach suburbs are 9km away from Walvisbay, en route to Swakopmund. Swakopmund and Hentiesbay are linked via a salt-surfaced road, 67km long. Lüderitz's main approach is from the inland. Short sections of the Walvis-Swakop road are lower than 10m above sea level, but large extents of the Swakop-Henties road lies below this critical level.

c. Electricity

- i. No significant impacts are predicted for current and near-future infrastructure planning. Increased attack on electrical infrastructure may be a possibility by the increase of corrosive elements in the atmosphere due to the higher sea temperatures and deeper penetration of the sea inland.
- ii. In the case where wind power parks are developed along the coast (as is currently under investigation), it may be that when incorrectly sited, these wind turbines could suffer extensive damage due to corrosion and erosion if not relocated at great expense and effort.

5.13. Conclusions

5.13.1. Timeline and risk calculations

It is clear from the foregoing analyses that if sea level rise occurs, it could have extensive impacts that would result in high financial losses. At the same time it is also clear that the time spans involved are great (significantly more than 20 years) and certainty is correspondingly low. It is problematic and also unrealistic to make forward looking statements on these timescales, therefore only the present day worst-case and the 2030 business-as-usual scenarios should be considered for further planning.

5.13.2. Foregone development costs

To suggest that the potential financial impacts described above represent the net economic impact of sea-level rise for Namibia would be misleading. The replacement of salt road for

example can be viewed as a financial loss or as a fiscal injection aimed at stimulating economic growth, for example.

By assuming that financial cost is the same as economic impact, economic impact tends to be exaggerated. At the same time, where risks assessments confine their scope to the financial losses associated with infrastructure, instead of including the changes that are induced by these financial losses, **they tend under-report the full extent of impacts**, and leave a portion of risk that is unattributed to its underlying cause.

Sea-level rise, where it impacts upon the Namibian coastline, will result in a resource reallocation. The net economic impact of this reallocation after all impacts have filtered through the national economy, is what counts but typically this can only be estimated by applying a social accounting matrix (SAM). Namibia has a dedicated SAM constructed by NEPRU, but this was not available to this study.

In the absence of a SAM it is important to note that the primary impacts of sea-level rise on coastal infrastructure will be accompanied by secondary implications which themselves will involve costs and benefits. Fiscal resources allocated to the replacement of electricity infrastructure, necessarily imply fewer public funds for other public infrastructure or development priorities. Private sector expenditure on the refurbishing of damaged holiday homes, either raises the costs of insurance premiums for everyone or, when uninsured, comes at the expense alternative consumption expenditure.

Specific cases will differ, but from a policy perspective it is important to note that this reallocation tends to be regressive: that is the cost of reallocation impacts disproportionately on the poor. In conjunction with the observation that poor people and households tend to, due to their direct dependence on natural resources their inability to access insurance and their lack of contingency funds, to be adversely affected by environmental change (including sea-level rise), the policy implication is for efforts that deliberately acknowledge differential vulnerabilities in the face of sea-level rise. These can be difficult if economic impact studies do not include the opportunity cost (the cost of foregone options) of sea-level rise events.

A further, often neglected, dimension to the cost of sea-level rise relates to the scope for mal-adaptation. Responses to these events, even when well-meaning can inadvertently make things worse for some people. The construction of sea-walls represents a good example. A United Kingdom study of sea-walls around that coastline established that only in 38% of the opportunities did they actually reduce impacts, while in 18% of examples they exacerbated impacts. In spite of their popularity, it is difficult to build an effective sea-wall. Unless the risk of amplifying costs through the response to the primary event is imputed into assessments and decision making, the impact of these events tends to be under-reported.

5.13.3. Key finding with regard to future studies

Public and private stakeholders should work towards the preparation of realistic medium and long term development planning, specifically in these coastal areas, which would in

future allow studies such as this one to make realistic forward-looking predictions of impacts on infrastructure, development and the economy(ies).

5.13.4. Risk calculations

The value of the risk is estimated via the formula that multiplies the probability of the respective Scenarios 1 to 3 sea-level rise events by the sum of the damage inflicted by the respective events. Damage is captured aggregating the financial and other losses mentioned above for property infrastructure, tourism. Whilst the opportunity cost of foregone development and the loss of ecosystem goods and services **should** be included in this risk calculation, the lack of reliable data with which to impute these impacts has lead to their omission. The result is an almost certain, but small, under-reporting of sea-level rise risk, a fact that should be included in the inference drawn from this study.

$$R_e = f_e \sum (\textit{loss of private property value} + \textit{loss of tourism revenue} + \textit{loss of public infrastructure})$$

Where f_e represents the probability of a sea-level rise event e , where “e” is a sea-level rise event as described in Scenarios 1 to 3.

6. Environmental Analysis

By Lucinda Fairhurst (Laquar Consultants, July 2009)

Identification of impacts of sea level rise and storm surges on biodiversity and the environment

6.1. Introduction

The IPCC's 4TH Assessment clearly recognizes that the observed increase in global temperatures is due to increases in anthropogenic greenhouse gas (GHG) concentrations' (IPCC 4th AR, 2007). These observations have been accompanied by increases in average air and ocean temperatures, an increase the melting of snow and ice, and thus an increase in mean sea level and observed by scientists globally. In the IPCC's 4TH Assessment the global mean sea-level rise scenarios are based on thermal expansion and ice melt which projects an acceleration of up to 2.4 times compared to the 20th Century' (Nicholls *et al.* 2007).

While GHG emissions reduction at global and local levels can help to slow the rate (although there is no evidence to suggest reduction is taking place), climate change cannot be prevented entirely. Increases in mean sea levels therefore, are going to be a long term problem. Throughout the 20th Century the observed rise in mean sea level has contributed to increases in: coastal inundation, salt water intrusion, erosion and ecosystem losses. The impacts of sea level rise are further exacerbated when we consider them in conjunction with the other effects of climate change such as increased storm intensity, wave action and temporary flooding which will have adverse effects on coastal communities and ecosystems (Nicholls *et al.*, 2007, Nicholls & Leatherman, 1994).

Within Africa there have been a number of investigations undertaken in order to ascertain the rate of sea level rise in relation to local historical records, projected rise; and identify it's impacts on the infrastructure, services and human populations with attempts to identify the most relevant adaptation options. A study carried out by the World Bank (Dasgupta, 2009) investigated how the combination of increasing sea level rise and more frequent storm surges will affect Sub-Saharan Africa. The report essentially assigned ranks to the countries that are most likely to be the worst affected. Out of 29 countries within this region that have coastline, Mozambique, Madagascar, Nigeria and Mauritania will reportedly account for 53 % of the total increase in the regions surge zones, as a result of sea level rise and intensified storm surges. Further, it is estimated that due to mean sea level rise and increased storminess, countries such as Mozambique, Ghana and Togo may loose more than 50 % of their coastal GDP. These countries were then re-ranked according to their coastal agriculture and the extent to which the croplands are projected to be affected placing Nigeria, Ghana, Togo, and Equatorial Guinea as the four most threatened. While the report does not quantitatively identify the loss of ecosystems within these areas, it does note that the damages to coastal wetlands are likely to be as high as up to 82% of the coastal wetlands of Namibia.

The loss of coastal wetlands and mangroves and their importance as fish spawning areas was highlighted by Titus (1990). As with the majority of current literature available, whilst the loss of these ecosystems is identified, the emphasis is most often placed upon the loss of land and physical structures that will be detrimental to the human populations residing within the coastal regions. Coastal wetland decline has been noted in Gambia (Jallow *et al.* 1996), the Atlantic coast of North

America, the Mediterranean, the African Atlantic coast, South Asia and Australia (Nicholls *et al.* 1999) and South Africa (Cartwright *et. al.*, 2008 and Mather, 2007).

In 2008 the City of Cape Town commissioned a report to model predicted sea level rise and storm which made use of a range of scenarios in order to understand the impacts on the coastal systems, infrastructure and services provided by the City (Fairhurst, 2008) whilst also identifying options that may be used to improve for future preparedness and adaptive capacity (Cartwright *et al.* 2008). The report included a cost benefit risk analysis that associated the probability of occurrence with the severity of the event. It also identified a number of biological options that can be employed in response to sea level rise, such as dune cordons and estuary and wetland rehabilitation as a mechanism of reducing coast and risk associated with increased preparedness and reduced vulnerability.

It is evident that sea level rise will impact coastal ecosystems in a number of ways. Increasing sea levels will inundate wetlands and low-lying areas, erode beaches and coastal areas, intensify flooding, and increase the salinity of estuaries and aquifers. Other effects of sea level rise include changes in sedimentation patterns, decreased light penetration and altered tidal ranges to name a few. From the available literature it is clear that the majority of investigations are performed with an emphasis on the socio economic effects of sea level rise and not its impacts upon the ecosystem. Whilst it is easier to quantify the loss of infrastructure and services in monetary terms than it is the loss of ecosystems and their services, it is vital that they are considered and taken into account when trying to ascertain the value of the threat and risk. The ecosystems that exist within coastal zones are vital for many livelihoods such as: the provision of food (fishing), natural medicines, recreation as well as providing habitats and nursery grounds for a wide range of fauna and flora. Further to this, healthy natural systems provide vital biological protection by acting as a 'buffer' against the effects of sea level rise as highlighted in the City of Cape Town Sea level rise investigation (Fairhurst, 2008 and Cartwright *et al.* 2008).

The coastline of Namibia stretches for 1500 km and is vulnerable to the effects of sea level rise (UNFCCC, 2002). Climate change is likely to exert pressure upon the Namibian coastline through a number of processes such as increased erosion, flooding and saltwater intrusion and may even lead to shore line retreat (EcoAfrica Environmental Consultants, 2009; Douglas *et al.* 2001; Grossman and Johnson 2008).

In 2009 the UNFCCC commissioned this project to model the effects of sea level rise on the Namibian Coastline. The initial report utilizes three scenarios in order to identify the locations of the coast that are to be considered as vulnerable to sea level rise and its associated impacts (Brundrit, 2009):

- Scenario 1: **Present Day Worst Case Scenario** of extreme sea levels for use in the GIS Inundation Model for the coastline of Namibia. This model is based on existing mean sea levels and is taken to result from the simultaneous occurrence of an extreme storm, an event with a nominal return period of 100 years. This scenario distinguishes between sheltered, exposed and very exposed coastal environments.
- Scenario 2: **Scenario at year 2030** through the extrapolation of the current situation in order to assess the likely trends in the near future. As it is predicted that as human induced climate

change continues to cause sea level rise the degree to which sea level rises is likely to accelerate in the near future, causing a 20cm rise from the base levels by 2030.

- **Scenario 3: Polar ice melt scenario** focuses on the longer term consequences of sea level rise and its effects on the coastline. Here the focus is on mean sea level rise and the changes that could be expected from ice melt alone. This will map the new predicted coastline that would be expected under these conditions.

The report considers the major population centers along the Namibian coast line namely: Oranjemund, Luderitz, Walvis Bay and Swakopmund. Due to topographic and distance from the coast, it was identified that Walvis Bay is under threat to the immediate impacts associated with sea level rise. This initial report (Brundrit, 2009) has been compiled with the intention of serving as a part of a compilation of reports that are intended to identify and establish the most vulnerable aspects of the coastal zone with particular emphasis on infrastructure and services, socio-economic and ecosystems sectors.

For the purposes of this particular report, the author intends to examine and highlight the effects of sea level rise and its associated impacts on the coastal ecosystems of Namibia whilst providing an overview of the existing governance system of Namibia's coastline. The policy, regulatory and institutional framework is assessed in terms of its adequacy for integrated coastal zone management, and its potential for implementing effective adaptation strategies to sea level rise. The report illustrates the interactions between the relevant stakeholders and identifies a number of gaps and conflicting mandates in the legislation leading to a number of causes of the current managerial deficiencies. Tailored adaptation and improvement strategies which incorporate the Namibian coastal ecosystems are therefore recommended for effective coastal management.

6.2. **Sea Level Rise and the Namibian Coastal Ecosystems**

This report is based on the best available data for estimating the relative vulnerability of various coastal locations to increased storm surge events and, in the longer term, mean sea level rise. However, there are several gaps in the resources available and the data has limited detailed downscaled analysis. First and foremost, the absence of reliable spatial mapping of coastal and marine fauna and flora and populations has prevented the incorporation of detailed localised analyses and interpretation. Human activity in the coastal locations discussed below is generally increasing more rapidly, so the impacts highlighted in this document may be considered conservative on this score. It is also worth noting that counteracting adaptation and mitigation measures related to land-use planning and relocation have not been included. Better local modelling of the biota and topography would assist in these analyses. Henrik *et. al.*, (2009) reports to have mapped the priority areas and habitats using gradients in biodiversity, distribution and on the basis of landscape characteristics known as important environmental drivers, etc. However, it should be noted that the author was unable to locate these maps prior to the compilation of this report.

Coasts are dynamic systems undergoing adjustments in form and process at different temporal and spatial scales in response to a number of physical factors such as geomorphology and oceanography. Human activities occurring on the coast place increased strain upon, and can overshadow the natural processes. It is projected that Namibia will experience significant increases

in the percentage of their coastal urban extent falling within the surge zone when considering sea level rise and storm surges. As far as coastal wetlands are concerned, and in terms of area measured in square km, up to 82% of the coastal wetlands of Namibia are documented as being susceptible to significant damages from sea level rise and intensified storms (Dasgupta *et.al.*, 2009).

Coastal marine systems are among the most ecologically and socio-economically vital on the planet. Recent climatic trends, which are a fraction of the magnitude of the projected changes in the coming centuries, have already triggered significant responses in the Earth's biota (IPCC, 2001). In this report it is emphasised that natural systems, and those with high biodiversity in particular, provide a number of services (these are called *ecosystem services*) which are vital for anthropogenic systems:

- Replenishment of groundwater
- Oxygen production
- Flood attenuation
- Atmospheric carbon sinks
- Filtering of run-off and air pollution
- Tourism draw-card
- Provision of medicinal and other natural products
- Recreational, cultural, educational, spiritual values
- Artisanal and subsistence fishing and agriculture

With the aforementioned dynamic and ecological processes in mind these ecosystem services, in the Namibian context, are illustrated below:

The **fishing industry** is a source of substantial employment in Namibia, and the sector is the second largest contributor to the GDP. Significant research and management resources are directed towards establishing a sustainable fishery (Henrik *et al.*, 2009). The off-shore commercial fishery represents the largest component of the fishing industry in Namibia. This can be subdivided into the pelagic and demersal fisheries, where species such as Hake, Sardine, Anchovy, Sole and Kingklip are actively targeted. With regard to the in-shore fisheries, Henrik *et al.*, (2009) stated that commercial or subsistence fisheries do not occur in the coastal region as a result of exposure to oceanic swell and waves and the lack of access although angling, remains popular and is subject to permit and catch limits of exploited stocks such Steenbras. It should be noted that according to the MFMR it is prohibited to have an impact on the marine environments 'in such a way that it may be detrimental to the marine life ecosystem'. The most obvious impacts that sea level rise is likely to have on these resources are inherently coastal, particularly in the shorter term. With the projected increasing frequency, intensity and duration of sea storm surges, it is the coastal/marine interface that is likely to be put under the most pressure as habit changes, destruction, changes in primary production and such an extreme physical stresses are most likely to have adverse effects on the coastal spawning and nursery grounds and thus reduce the replenishment rates of the natural stocks. In the longer term, the effects of mean sea level rise is likely to impact upon primary production in coastal systems but may largely be dependent upon variations in the nutrient concentrations caused by changes in ocean current patterns and upwelling regimes (Harley, 2006). The Benguela upwelling system, high rates of offshore transport are proposed to favour producers by transporting herbivorous zooplankton out of the near-shore system. The deposition and decomposition of surplus

phytoplankton biomass on the sea floor have been linked to large eruptions of methane and hydrogen sulphide, which in turn lead to hypoxia and increased mortality of near-shore animals such as rock lobsters and Cape hake (Bakun and Weeks, 2004).

Sea level rise could have important implications for **shore birds** that rely on coastal organisms for foraging habitat during their migrations and nesting sites. Namibia currently supports large numbers of migratory birds on local and international levels. If major intertidal habitat losses occur as a result of destructive wave action during sea storm surges or permanent inundation of saline waters with mean sea level rise, this would jeopardise the ability of the Namibian coast to continue to support their current migratory and shore bird numbers. The most severe losses are likely to occur in areas where the coastline is unable to move inland because of human development and/or coastal defence structures such as sea walls. The combined effects of habitat change and breeding areas could potentially have even more severe effects.

6.3. Impacts associated with Sea-level Rise:

6.3.1. Coastal erosion

The rate of coastal erosion is not only dependent upon sea level rise and storm surge events, but also upon rainfall patterns and intensity as well as the type of coastal development, geomorphology, and the geological make up of the coast. However, in general, an increase in coastal erosion and risk of landslides due to sea level rise, storm surges and changes in rainfall can be expected. Coastal areas are becoming increasingly artificialised and fixed through development. The potential therefore to encounter coastal dynamic processes (which happen naturally anyway) is increased. The exposure to coastal dynamic processes will be compounded given the predictions of increased storm surge events and sea level rise. Therefore, coastal erosion is likely to become accelerated as a result of the systems such as dunes and beaches not having enough time between storms (increased frequency and intensity) to replenish themselves (sediment transport and deposition).

When considering erosion rates, the diversity of Namibia's coastline should also be accounted for. Some of these factors are, for example:

- Sandy coasts that have been disturbed are likely to become bias to erosion. If beach and dune systems are healthy and pristine, they tend to cope fairly well with erosion.
- Cliffs are also likely to become more sensitive to changes in drainage and moisture processes resulting from a combination of sea level inundation and changes in rainfall and precipitation patterns.
- A combination of rocky shores and sandy beaches most often display increased rates of erosion (as opposed to pure rocky or pure sandy shores).
- Human influences such as the degree to which the shore has been altered and developed will play a decisive role in the magnitude of the impacts and threats associated with coastal erosion.
- Alterations in water tables are also a factor that should be considered as higher water tables increase wave run-up and speed of backwash thus increasing the potential for erosion.

- Height of waves.

Ports and harbours have long been part of the preferred logistical network for nations to trade. To illustrate the threats and impacts highlighted above, the town of Swakopmund has been selected.

Swakopmund is the capital of the Erongo administrative district and is Namibia's second largest town. It is located on relatively high ground, to the north of the mouth of the ephemeral Swakop River (Brundrit, 2009). As of 2007, Swakopmund's population is approximately 28,552. Swakopmund is the premier holiday resort in Namibia, during the summer holidays and long weekends thousands of Namibians flock to the coast. This immigration happens for a number of reasons, for recreation and holidays, and during the December and January the cool Namibian coast offers relief from the intense heat of the interior. It is also the primary destination for 17% of all tourists entering Namibia. A large retail sector has developed around the tourism industry as well the local population. This sector relies largely on unskilled and semiskilled labour, but is the largest source of employment in the town itself.

In terms of the economic activities, a number of different types of mining activities take place in and around Swakopmund such as: Sand, Uranium, Diamond and Salt. Sand mines in the Swakop River is in fact the only source of all grades of building sand needed for the construction industries of both Walvis Bay, Swakopmund and Henties Bay. The largest single employer (both in Swakopmund and in Erongo Region as a whole) is Rössing Uranium Mine. While the mine lies some 60 kilometres to the east of the town many of its workers live in Swakopmund and commute daily. Income obtained from employment at the mine therefore helps to support the local retail and service industries, creating employment. As a growing town, it has a healthy construction industry which has been supported by the growth of tourism and of new neighborhoods. The industry now employs close to 200 people regularly, but many more on a short-term basis.

Swakopmund is supplied water by NAMWATER, the public water supplier who pumps water from underground aquifers of the Omaruru and Kuisen Rivers and serves as a base from which to explore the surrounding desert and the list of activities offered is ever increasing. To name a few of these activities include: visits to the Namib Desert, Messum Crater (known for its diverse desert-adapted plants such as *Welwitschia mirabilis* which is one of the many endemic to Namibia (figure 1)), the seal colony at Cape Cross, quad biking and sand boarding. Fishing activities are vast and range from fishing for sharks and marlin to pilchards.



Figure 23: Image of *Welwitschia mirabilis*, an ecologically highly specialized endemic plant that grows in isolated communities in the Namib Desert

In terms of the biodiversity, and the ecosystem structures in the area, the Walvis Bay Biodiversity Report (LAB 2008) clearly identifies the dune belt area between Walvis Bay and Swakopmund as a location which is uniquely biodiverse and states its importance in terms of the heritage and tourism potential along the coast.

The marine biodiversity in and around Swakopmund has very little literature basis, although the ski boat, recreational fisheries in Swakopmund, and a variety of informal coastal activities have been documented and recommended for classification as artisanal fisheries (Batty *et. al*, 2005). The report describes the fisheries concerned, and provides some information available on the changes that have occurred in the past. This fishery itself has declined in recent years (MFMR unpublished data). Most ski boat owners have found the tourist trade to be more profitable than commercial fishing, and now offer recreational fishing, dolphin or seal watching and trips round the bay. Ski boats use handline gear to catch Kob, but mainly target Snoek (*Thyrsites atun*), when shoals of this fish are accessible. All of the above activities therefore rely hugely on the marine biodiversity and ecosystems of the region.

In general the Namibian coast is exposed to the full force of the Atlantic, but some shelter from wave-action is found in the artificial harbour at Swakopmund. The contrast between the rich algal flora of the intertidal region and the extremely barren desert lying directly behind the beach is stark. The organisms that are documented to occur in the intertidal zones are not considered to be uncommon on the South African west coast such as: the toothed barnacle (*Chthamalus dentatus*), the limpet (*Patella granularis*), the mussel *Perna perna* and large limpets which occur in thick clumped beds. More significantly however, changes of species composition at Swakopmund are documented most notably by Lawson (1990) where a reduction in frequency of the Cape rock lobster, *Jasus lalandii* was noted. A possible explanation for these changes was also provided as: the relative wind stress and concomitant water circulation which is reduced here and to the north. The impacts associated with climate change i.e. an increase in frequency and intensity of storms may lead to an increase in numbers although to substantiate this, further investigation is recommended.

Unfortunately, despite the above information, there was very limited information to be found on the local ecosystems and biodiversity (both terrestrial and marine) that was particular to Swakopmond. This should be considered an area of priority for research and biodiversity mapping if the current and projected development and growth of the town are to be realized.

The extremely dynamic sediment budget of the Walvis Bay area would make the effects of increased coastal erosion of limited importance to infrastructure (Hughes, 1992). Development has not taken place in the most dynamic and vulnerable parts of the coastline because these areas are traditionally recognised as unstable and undesirable. However, it is worth noting that the existing infrastructure magnifies the erosive effects of sea storm surges in the coast adjacent to Walvis Bay, which has been noted for its richly biodiverse fauna and flora (LAB, 2008).

There are very few coastlines in the world today that are beyond the influence of human pressures despite the fact that not all coasts are inhabited (Nicholls *et al.*, 2007). The major direct impacts as stated by Nicholls *et al.* (2007) include: the drainage of coastal wetlands; deforestation; reclamation; discharge of sewage, fertilisers and contaminants into coastal waters; sand mining; harvesting of fisheries and other living resources; and the introduction of sea-walls, other structures and invasive species. The aforementioned activities often result in the hardening of coasts, changes in circulation patterns and are often responsible for altering freshwater, nutrient and sediment delivery. Using the two locations provided above, it is apparent that coastal erosion and the extent to which it likely to impact upon these towns and their economies is very different ways due to their location and topography. However, given the ecosystem services that are offered in these areas i.e. as a tourism draw card, stresses and shocks induced by sea level rise could undermine the resilience of the socio-economic systems that are dependent on these. The loss of substrate binding plants resulting from increased susceptibility to storm surges resulting in sea water inundation will increase erosive effects, soil damage and possibly landslides. It should also be noted here that the projected increased frequency of storm events will not assist in the replenishment of soft sediments.

6.3.2. Saline intrusion:

A rise in mean sea level is projected to slowly inundate wetlands and lowlands resulting in an increase in salinity of estuaries and aquifers and otherwise impair water quality, alter tidal ranges in rivers and bays and change the locations where rivers deposit sediments. The richly endowed coastal zone of Namibia is anticipated to be adversely affected by this eustatic rise due generally to the low-lying nature of the coastal zone. The coastal areas of Namibia are important ecologically because they provide spawning and nursery grounds for many coastal fish species. They also serve as habitats for numerous crustaceans and molluscs. Increased salinity in these areas is likely to lead to the decimation of organisms that are not resistant to the high saline environment. The freshwater aquifers which support most of Namibia's coastal human populations could be polluted with saline water and soils. In turn, this could decrease water security for impoverished populations, who already have limited access to secure and potable water supplies. Salinity stress consequences

resulting from saline intrusion may lead to the disruption of faunal and biotic assemblages and thus result in the redistribution of species and failures in the reproduction and survival of their eggs/spores and larvae.

The two case studies that have been selected to demonstrate to anticipated effects are Henties Bay and Walvis bay.

Henties Bay is regarded as the fishing Mecca of the Namibian coast, it is a major tourism hub and is a gateway to the skeleton coast and the Namibian desert. It is a small town with a population of about 2700 permanent residents and is a popular holiday resort. There is a nine hole golf course which is positioned in the former lower outlet of the Omaruru River and is surrounded by long stretches of sandy beaches. The Omaruru River is a linear oasis formed by dense woodland, and is supported by the periodic flood recharge of underground water along the course of the river. The River divides Henties bay into two parts, the north dune and the south dune and its mouth was developed into an artificial wetland in 2001. This wetland serves as an island for birds to forage and roost.

The region, known as the Erongo region, in which Henties Bay is situated is hyper arid and the town is solely dependent upon ground water resources to supply its water demand through municipal boreholes. Despite this, the areas within and surrounding the town are rich in biodiversity, which encompass a variety of marine intertidal rocky shore organisms, coastal dune systems and numerous bird species. The intertidal rocky shores comprise of a number of rock pools which are of particular interest as many marine organisms are located here, some of which are considered rare. The coastal dune systems are well established in certain areas and are characterised by hummocks and various species of vegetation which are typical for Southern African coastal dunes. Further inland, the Omdel Dam is located 45km from the mouth of the river and because of the damming, the Omaruru no longer supports healthy flora and fauna populations (NACOMA, 2009). The dam, when is has water, attracts numerous bird species including the rare Damara Turn (*Sterna balaenarum*) (figure DT) which is listed as near threatened (NT) (IUCN, 2009).



Figure 24: The Damara Tern

The local economy is small and very dependent upon the tourism and fishing industries (this does not include artisanal and subsistence fishers as the general view amongst government officials was that there was no artisanal fishing sector in Namibia in 2005 (Batty *et. al.*, 2005). At present there is a community based gardening project which is situated on an old delta on the Omaruru River. This project currently employs over 40 people and was initiated as part of a municipal job creation exercise. The vegetable produce from this project is reliant upon the municipal boreholes for irrigation and is sold locally. Tourism is considered to be the driving force of the Henties Bay economy. The tourism sector in this area embodies a number of activities such as off-road driving, angling and hiking and for the purpose of this report, it should be noted that the majority of these activities are directly dependent upon the coastal ecosystem services. Therefore any loss of these systems and increased pressure on fresh water resources could severely undermine the economy of Henties Bay.

Much of the town of Walvis Bay lies below two metres elevation. When considering the impacts of even a small rise, the ability of the town to survive may be substantially reduced. The increased intrusion of the saline wedge into the Kuiseb aquifer is something that should be managed and accommodated by judicious freshwater extraction. Sea level induced intrusion is secondary to freshwater demand (Hughes *et al.* 1992). The possibility of inundation, water logging and flooding of Walvis Bay is of greater consequence.

Salt water intrusion: Will likely cause alterations of ecosystems and habitat, in particular in the Walvis Bay Wetland where the species richness is highly dependent on a number of ecological interactions and systems, and salinity levels play a major role (Walvis Bay Biodiversity Report, 2008). The Kuiseb aquifer is also vulnerable to salt water intrusion, and especially if water is extracted too excessively which would allow for the saline wedge to move inland. Loss of indigenous vegetation and increases in alien invasive species (which tend to use more water than indigenous plants) could also exacerbate this process.

Most of the water used for domestic and industrial activities within the Namibian coastal zone is derived from groundwater sources. This is due of the absence of any large surface water supply due to the high evaporation rate resulting from the high temperatures. The growing coastal activities have attracted large populations to the coast which have in turn applied substantial strain on these groundwater resources. The depth-to-water-table in most coastal zones is often very shallow and therefore subject to saline sea water contamination and pollution. An increased global sea level rise is expected to raise the water-table along the coast and result in increased salinity of the ground water.

The aforementioned impacts is likely to result in increased competition for water from agricultural and urban demands, and/or estuaries and wetlands which need freshwater for flushing and maintaining salinity profiles (Mukheibir and Ziervogel, 2006). Increased temperatures and sea level rise will increase the pressure on estuaries and wetlands and subsequently stress natural and anthropogenic systems. Presently, many indigenous species are also under threat from influences such as invasive alien species, poorly planned development and land use and inadequate management.

Notwithstanding the detrimental impacts to ecosystem integrity and biodiversity associated with saline intrusion, increased salinity and higher water levels may lead to the provision of new habitat availability that may serve as coastal spawning and nursery grounds for marine organisms. Although salt water intrusion is anticipated to adversely affect the biodiversity that currently exists in coastal low-lying areas, as the salt water is too harsh for these organisms to survive. The increased water depths and spatial availability may provide a new niche for a number of coastal fish species, ie: those that belong to the Sparid family.

Sea level rise can affect the nature of coastal areas in two ways:

- Currently flooded areas will become deeper as the water level rises therefore causing a transition from riparian wetlands to open water.
- Additional areas will become increasingly flooded and result in a transition from terrestrial fauna and flora to riparian wetlands.

6.3.3. *Raised water tables*

Rising sea levels will affect organisms, both flora and fauna, found along the rocky shore. Migration of certain organisms may occur in response to these higher levels. According to Skilleter *et al.*, (2008), and Bird, (1993), rocky shore communities provide an ideal system to investigate the impacts of climate change and sea level rise. It has been suggested by Wanless, 1992, that organisms such as barnacles and oysters will shift their distribution up-shore in response to sea level rise.

With raised water tables anticipated to be associated with mean sea level rise, problems are expected for the future of drainage systems. This may lead to an encroachment of polluted water into wastewater treatment and thus the probable adverse effects associated with sewage overflow. Sewage overflows are hazardous in terms of human health; and for the natural ecosystems' health as untreated faeces is considered to be a pollutant in the natural environment. Raw sewage contains digestive enzymes. These digestive processes may continue in untreated sewage and thus degrade the soft sessile organisms. In terms of the floral biota, sewage has been known to smother photosynthetic plants, ie: Cape Town, South Africa, 2008.

Increased groundwater levels are likely to increase the vulnerability of communities that are located in low-lying areas, where rain water and sea storm surge water will no longer be able to dissipate thus exacerbating flooding impacts. Changes in the water table levels will also impact upon the soil moisture content. The fluctuations in moisture may lead to the ground expanding and contracting. If these differences occur quickly over a short space of time (as can be expected in this hot desert environment), it may lead to landslides. Landslides cause a great deal of disruption in the immediate vicinity. The impacts on the biota occur in two ways:

- The immediate loss of fauna and flora as the landslide occurs, ie: those on cliff faces that fall and suffer damage
- Smothering of and damage to those positioned below the landslide

For impacts associated with higher water tables, please see those mentioned above as a result of salt water intrusion.

6.3.4. Storm surge events: Walvis Bay

In present day circumstances and furthermore, by the end of the next decade, the anticipated increases in frequency, intensity and duration of storm surges will undoubtedly affect coastal biodiversity in numerous ways. Firstly, by increasing erosion rates and soil damages; and secondly by increasing salinity particularly in the coastal wetlands environment. The impacts will depend upon each ecosystem's ability to sustain themselves during these events and the amount of time required to replenish themselves after such events (although the amount of time available between surges is anticipated to become shorter) (Brundrit, 2009). Coupled with this, it is worth noting that the impacts associated with sea storm surges encompass all of the impacts projected to occur with mean sea level rise. Although one must be aware that the impacts relating to inundation, ie: salt water intrusion, raised water tables and flooding are non permanent isolated events. It is however during these events that substantial erosion occurs over a short period of time and are thus noticeable.

As mentioned above, the loss of substrate binding plants resulting from increased susceptibility to storm surges will further exacerbate erosive effects, dune damage and landslides. The increased frequency of storm events will not assist in the replenishment of soft sediments. This is likely to threaten the basic services offered by the natural ecosystem, thus reducing the natural resource capital. Dunes act as buffers to wind and have historical, cultural and heritage value. A decrease in the aforementioned buffer may also result in a reduction of agricultural and garden productivity as strong winds reduce plant growth.

Most species are expected to be able keep pace with projected levels of sea level rise, with the exception of some slow-growing long-lived species. However, dramatic ecological changes could result from these extreme events decreasing habitat availability within a particular zone. This is likely to have obvious implications for intertidal and shallow subtidal systems that are vulnerable to hydrodynamic disturbance. Hydrodynamic disturbances from storm waves set upper distributional limits (Graham, 1997). This is because storm waves have extreme power and ability to dislodge organisms that are not permanently inundated during the time of the storm. Southward *et al.* 1995, demonstrated changes in the abundance of North East Atlantic taxa ranging from kelps to barnacles and zooplankton to fish.

Due to the topography and exposure ratings associated with Walvis Bay, the threat associated with sea level rise is immediate through sea storm surges. In terms of its economy, Walvis Bay is the main tourism centre of Namibia, mainly due to its large bay and sand dunes which provide unique natural environments and popular recreation areas. The harbour is the hub of the main economic driving force, and the harbour itself employs a large part of the local population. The main industry is fishing, followed by salt production, and the harbour is a major trading point for Southern Africa (Walvis Bay

municipality, 2009). Most industries in Walvis Bay are directly or indirectly dependant on the town's unique and sensitive coastal environment, for example the Salt Works, guano production (on Bird Island) and oyster farming. The Walvis Bay salt field produces 700 000 tonnes of salt each year out of 24 million tonnes of sea water, and the Salt Works also support half of the total number of birds in the lagoon area as they feed from the continuous inflow of particles and nutrient-rich water which supports the benthic and pelagic food-chain. The Salt Works also is one of the largest solar evaporation facilities in the world, and it employs more than 100 people (Walvis Bay Biodiversity report, 2008).

Walvis Bay has a semi-sheltered marine environment with a low-lying harbour (less than 2m above mean sea level), and due to the extremely arid conditions the town is completely reliant on its coastal aquifer for fresh water (Hughes *et al.*, 1992). The unique marine environment is a result of its sheltered and shallow shoreline protected from the sea by a 10km long sandspit (Pelican Point); a feature that is rare for the Namibian coast. The harbour itself provides rare (artificial) habitats for indigenous sessile marine animals such as mussels, barnacles, tube worms, sea squirts and lace animals, as these species are often found attached to the harbour walls. Pollution from fish factory effluent is however a threat to these habitats, and species numbers are being significantly reduced.

In conjunction with the unusual interaction between coastal wetland and the desert, it is further signified by rich and diverse habitats for flora and fauna, which are divided into four biodiversity areas according to their characteristics and functionality (LAB, 2008). Two of these are regulated under international conventions and agreements, namely the Walvis Bay Wetland which is a Ramsar site, and the Walvis Bay Coastline which has been designated as an Important Bird Area (IBA). The wetland has a nutrient-rich marine upwelling system that supports production of phytoplankton, zooplankton, marine invertebrates, fish and marine mammals, making it attractive for birds and cetaceans. An important part of the wetland is the Walvis Bay lagoon which is one of the world's best flamingo viewing localities, and birds are the primarily conservation concern for the lagoon. The inner part of the lagoon is a highly sensitive ecological area, hence motorised boat access has been limited to the lagoon, which otherwise is very popular for recreation activities. Oyster production in the lagoon has been a financial success, and this activity currently poses no threat of concern to the ecosystem.

The Walvis Bay coastline makes out an area of 30km of the Namibian coast, and it has up to 770 (LAB, 2008) bird species per kilometre of shore which is the highest linear count of birds in Southern Africa. The famous Bird Island is the only place in Namibia where the Eastern White Pelican (*Pelecanus onocrotalus*) breed, and where Cape Cormorants (*Phalacrocorax capensis*), White-breasted Cormorants (*Phalacrocorax carbo*) and Crowned Cormorants (*Phalacrocorax coronatus*) roost. The endangered Damara Tern (*Sterna balaenarum*) also has one of its most important breeding areas on this coastline. It should also be noted that invertebrate densities are higher here than on any other beach in Southern Africa, and as a result (and in conjunction with a number of other ecological factors, such as stranded kelp, algal and zooplankton blooms and the sheltering effect of the Pelican Point Peninsula) the Walvis Bay coastline hosts exceptionally diverse and rare habitats to a great number of species, some of which are endemic and endangered.

The Kuiseb Delta features significant ecological and cultural values, and it is also the home to the indigenous Topnaar community which are the primary users of the natural resources found in the delta. Within the delta and the Kuiseb river low number of plants exist that are adapted to the very dry conditions, for example *Salsola* shrubs, dune grass, dune succulent shrubs (*Trianthema herereoensis*), camelthorn (*Acacia erioloba*), anaboom (*Faidherbia albida*), wild ebony (*Euclea pseudebenus*) and tamarisk (*Tamarix usneoides*). The spreading of invasive alien species is a growing problem in the delta as is the increase in vegetation loss due to soil erosion (largely due to off-road vehicles and overgrazing). The Kuiseb aquifers provide the national water supply with large quantities of water, an activity that could be undermined by various factors (e.g. salt water intrusion and erosion) if not carefully monitored and managed (Walvis Bay Biodiversity Report, 2008).

The Dune Belt area stretches from the Walvis Bay harbour to the Swakop river, and has a high and unique diversity of desert adapted flora and fauna, and it is further one of the main habitats for the endangered Damara Tern. Dry conditions make it a low-energy area, and any damage to the ecosystem subsequently takes a long time to repair. The common vegetation is the succulent and endemic shrub *Trianthema herereoensis*, which supports large amounts of animals in the dune system. Two endemic rodents are also found in the dune system, the Golden mole (*Eremitalpa namibensis*) and the Namib dune gerbil (*Gerbilurus tytonis*). The numbers of Tenebrionid beetles serve as indicators of environmental conditions, as their populations are dependent on a wide variety of integrated factors. This area is also very popular for recreation activities, which have increased over the past few years and is causing degradation of the ecosystem (Walvis Bay Biodiversity Report, 2008). The ecologically sensitive Dune belt area is already suffering from erosion and habitat loss due to anthropogenic factors, and flooding, salt water intrusion and raised water tables is mostly likely to exacerbate such processes.

Possible impacts on the sandspit, like for example erosion and/or raised water tables resulting from sea level rise, may reduce the protection it currently offers to the harbour. Consequences in terms of the human and ecosystems could be vast as the sandspit functions as a natural barrier against waves and currents.

6.3.5. *Invasive alien species:*

There is limited knowledge regarding invasive alien species and their response to climate change. The increased distribution and densification of invasive species will impact upon the indigenous fauna and flora due to competition for space and food. Many invasive alien species already compete with indigenous species. This will likely impact on their suitability to this altered environment but it is unclear how. Changes in the abundance and distribution of individual species cannot currently be predicted with absolute certainty: robust patterns have emerged from the available research literature and therefore climate change and sea level rise should be considered in conservation planning. Fragmented ecosystems will be the most vulnerable to the anticipated changes in sea level (both permanent and storm surges).

The distribution of alien introductions is advised to be carefully monitored in relation to the growing aquaculture and mariculture industries.

6.3.6. Flooding and inundation:

The evidence that climate change is happening and will continue to occur in ways that affect the planning and day-to-day operations of local government's line functions and communities is now overwhelming. International opinion is that climate change will manifest itself through mean sea level rise; more frequent and intense extreme events of longer duration extreme events such as sea storm surges. However, sea level rise is not the only climatic variable which local, provincial and national governments should be concerned with. Other climatic factors such as altered rainfall patterns and rising temperatures which may lead to heat waves, droughts and flash flooding are projected to occur.

In this sense, Oranjemund has been chosen due to its geographic location near the Orange River mouth, and the fact that it is set well back from the coast. Its distance from the coast makes it unlikely that Oranjemund will be impacted from the projected effects associated with sea level rise in the immediate future, ie: storm surges. However, changes in rainfall and precipitation patterns are likely to impact upon the flow-rates, force and quantity of the Orange River water. Oranjemund becoming isolated as a result of its approach roads being flooded and/or washed away during an intense rainfall/flood event. Policy-makers should therefore consider this vulnerability when initiating development/infrastructure planning.

6.4. **The governance system of Namibia's coastal areas**

This section aims to provide the reader with an assessment of the existing governance system of Namibia for dealing with its coastline. The structure will follow an approach that highlights the barriers to effective coastline management, and then proposes tailored solutions. First, the concept of Integrated Coastal Zone Management (ICZM) will be defined, and definitions will be offered. Second, the report will assess the usefulness and adequacy of Namibia's legal, regulatory, and institutional framework for attaining ICZM. The analysis will attempt to draw out the root causes of the current deficiencies of coastal management in Namibia. Strategies that improve and strengthen coastal management will then be offered. This section does not purport to achieve an exhaustive assessment of Namibia's governance system. Rather, it aims to provide a stylised depiction of all the relevant stakeholders and the interactions between them, in order to draw out the implications this holds for effective ICZM.

6.4.1. Regional obligations

While an analysis of Namibia's current international obligations on coastal protection is beyond the scope of this report, it bears to be noted that integrated coastal zone management is not a one-country effort. The protection of coastal integrity must be undertaken as a concerted effort by neighbouring countries. Indeed, political frontiers have no bearing on ecosystems: ecosystems are only limited by their biophysical carrying capacity. Lack of consultation between countries that share a coastline would lead to sheltered and perhaps conflicting policies that undermine the biophysical and economic integrity of the coastline as a whole.

To this end, Namibia became a participant of the Benguela Current Large Marine Ecosystem (BCLME) programme. The BCLME was a regional initiative between Angola,

Namibia and South Africa to manage in a sustainable and integrated manner the living marine resources in the Benguela Current. The BCLME programme was funded by the Global Environment Facility and the United Nations Development Programme. It developed a legal framework to deal with trans-boundary environmental issues that are shared by these countries. The aim of this programme was to build structures and capacities that facilitate information-sharing and problem-solving in order to collectively protect this ecosystem. The BCLME programme has now been replaced by the Benguela Current Commission (BCC). The BCC is currently in its interim phase, and is running a Science Program until 2013.

6.4.2. Definitions

ICZM - The concept of Integrated Coastal Zone Management (ICZM) emerged in 1992 at the UN Earth Summit in Rio de Janeiro, and is set out in Chapter 17 of Agenda 21. The European Commission defines ICZM as:

*'a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, **all within the limits set by natural dynamics**. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space.'* (COM 2000 547 final [emphasis added])

The main themes of ICZM that policy-makers should strive to attain are:

- **Cross-sectoral integration:** concerted planning of sectors such as tourism, aquaculture, subsistence fishing, mining, and any other economic activity which depends on the coast.
- **Institutional integration:** coordination between the different levels of government (national, regional and local)
- **Sustainability:** coastal management that does not compromise the ability of future generations to use the coast, and does not supersede the reproductive capacity of coastal ecosystems.
- **Participation:** consultation of all the relevant stakeholders (indigenous communities, private sector, academia, decision-makers).

The underlying, and arguably most important point of ICZM, is that it takes an **ecosystem approach**: coastal policies must all be set “*within the limits set by natural dynamics*”. This recognises that every action has an effect on the components of an ecosystem, since

every living organism is linked, and that every policy must strive be holistic in its consideration of the impacts on the integrity of the ecosystem.

6.4.3. *Stakeholders in coastal governance*

a. *The State*

The 1990 Constitution of the Republic of Namibia states in Article 95, entitled 'Promotion of the Welfare of the People' that:

'The State shall actively promote and maintain the welfare of the people by adopting, inter alia, policies aimed at the following:

(l) maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future; in particular, the Government shall provide measures against the dumping or recycling of foreign nuclear and toxic waste on Namibian territory.' (Constitution of the Republic of Namibia, 1990: 45-6)

A constitution is the system of fundamental principles that the Government must use to guide the formulation of laws. As such, Article 95 does not grant legally enforceable rights to the State to pursue coastal protection.

Although the legal status of the seashore is not defined, Article 95 implies that the State should act as the Custodian of the coast on behalf of its citizens⁸.

b. *Line ministries*

The Government of the Republic of Namibia (GRN) has various Line Ministries whose mandates pertain to coastal management. These are:

- i. Ministry of Environment and Tourism (MET)
- ii. Ministry of Mines and Energy (MME)
- iii. Ministry of Fisheries and Marine Resources (MFMR)

c. *Regional councils*

The *Regional Councils Act 22* of 1992 provides for the establishment of a Regional Council for each of the 13 Namibian Regions. The four coastal regions are:

- i. Kunene
- ii. Erongo: Henties Bay
- iii. Hardap
- iv. Karas

The Regional Councils have the power to develop Regional Development Plans (RDPs).

d. *Local authorities*

⁸ It is argued that since Namibia has a Roman-Dutch law system (Common Law) heritage from South African colonisation, a competent court would determine that the coastline was property of the State only insofar as *res publicae* (NACOMA 2007a: 98).

The *Local Authorities Act 23* of 1992 establishes the system of local government in Namibia.

e. Decentralisation

The *Decentralisation Enabling Act 33* of 2000 provides for the devolution of powers vested in the various Line Ministries to Regional Councils and Local Authorities.

The ongoing decentralisation process will increase the pressures on the capabilities of under-staffed Regional Councils and Local Authorities. However, it should be used as an avenue for clearly defining roles, mandates and a common vision for the integrated management of Namibia's coastline.

6.5. Barriers to ICZM

Adaptive capacity is the ability of a system to evolve in order to accommodate climate changes or to expand the range of variability with which it can cope (IPCC IVth AR).

The combination of increases in mean sea level rise due to global climate change, with storm surges and projected intense tropical and extra-tropical storms, will result in extreme sea levels. Effective adaptation to sea level rise for coastal areas should include the implementation of ICZM.

Barriers to effective adaptation and the implementation of ICZM are:

- a) **Institutional/legal barriers:** institutional constraints and managerial deficiencies limit entitlements and access to resources and therefore increase vulnerability.
- b) **Informational/educational barriers:** successful adaptation requires recognition of the necessity to adapt (scientific understanding), knowledge about available options, the capacity to assess them, and the ability to implement the most suitable ones. The lack of education and trained personnel in the Regional Councils is a serious concern for the ability of the regions to implement ICZM.
- c) **Financial/market barriers:** poor regions tend to have less diverse and more restricted entitlements and are thus less empowered to implement effective ICZM.
- d) **Technological barriers:** the lack of technological capacity decreases the range of possible responses to sea level rise, such warning systems, protective structures, flood control measures.
- e) **Social/cultural barriers:** inequality in access to resources by vulnerable subsectors of the population will severely limit their ability to adapt to environmental risk.

6.5.1. Legislation

There are a number of areas of concern to be found with the existing legislation on coastal areas. They occur on all vertical gradients of policy-making process, from enactment to implementation, monitoring, and enforcement.

For example: At the enactment stage, certain key biodiversity hotspots are not afforded legal protection.

For example: At the enforcement stage, there appears to be a very poor record of compliance with environmental standards.

6.5.2. *Absence of legislation*

Some key biodiversity hotspots are not legally protected.

- a) The *Kunene River Mouth* lacks legal protection. Consequently, activities such as mining, tourism, and fishing are being carried out with no control, placing increasing stress on the wetland's natural resources. Furthermore, without adequate legal protection, proposed developments upstream, such as the Epupa Dam, could be approved with little or no consideration for the resulting environmental impacts downstream.
- b) Although the *National West Coast Tourist Recreation Area* is administered by the Directorate of Parks and Wildlife Management of MET, it has a lower protection status than a national park. This area is threatened by offshore mining and oil drilling. The increase in tourism is uncontrolled and unaccounted for. Furthermore, there is an expected growth in the fishing industries and aquaculture. A process has been initiated to claim the National West Coast Tourist Recreation Area as a national park.
- c) *Walvis Bay Wetland* lacks legal protection and effective zoning. Consequently, this site is subject to heavy human and industrial activities, and industries are expanding. Tourism activities such as off-road driving (motorised and non-motorised vessels) also contribute to coastal degradation.
- d) *Lüderitz Lagoon* also suffers from inadequate legal protection and zoning. The industrial development around the town and the harbour contribute to increasing pollution. Land is also reclaimed from the sea, putting the viability of coastal ecosystems and human activities on the shore at risk during extreme sea storm surge events. The unchecked mariculture developments also increase the risk of potential introduction of invasive alien invertebrate species, particularly when considered in conjunction with geographic distributional changes resulting from changing temperatures and rainfall patterns.
- e) The *offshore islands* are not currently protected under the law. Although there are no major threats to island ecosystems, offshore islands are very vulnerable to sea level rise. There is a dire need for adequate legal provisions to mitigate against the impacts of sea level rise in offshore islands. Nonetheless, in the first week of July 2009, the deputy Minister of Fisheries and Marine Resources, Kilus Nguvauva, officially launched the first Islands Marine Protected Areas (MPA) near Lüderitz, encompassing ten small islands and eight islets of rock. The aim of the MPA is to help maintain essential ecological and life support systems, to ensure sustainable utilisation of species and ecosystems and to preserve bio-diversity (The Namibian, 09 July 2009).
- f) The *Orange River Mouth* is an important site for diamond mining. It is not adequately protected under the law, which allows for uncontrolled prospective mining with little consideration for the effects this has on the local ecosystems. The Orange River Mouth would also benefit from a transfrontier management plan, which is not currently in place.

6.5.3. *Inadequacies of current legislation*

a. Compliance issues and weak enforcement:

Even when legislation is enacted to protect the coastal environment, it is often fraught with inadequacies. For instance, laws will carry penalties that are no longer adequate deterrents.

Governmental institutions have a poor record of implementing and enforcing the coastal safeguards that do exist. They often award concessions for prospecting and mining in areas with fragile ecosystems. A NACOMA report has even claimed that officials have allegedly facilitated illegal angling by tourists in protected areas (NACOMA 2007a: 4).

The conditions of approval for obtaining permission to build or create new development projects do not have stringent environmental standards. Moreover, monitoring of developers' compliance is weak, and even if transgressions are detected, there is little enforcement.

The use of environmental assessment instruments such as Strategic Environmental Assessments (SEA) and Environmental Impacts Assessments (EIA) is reportedly inconsistent. The reports are either of substandard quality or are ignored (NACOMA 2007a: 100).

b. Gaps in existing legislation:

The *Town Planning Ordinance 18* of 1954 allows local authorities to develop statutory development plans. However, these do not have the adequate legal basis to promote integrated coastal development plans. For instance, the restrictions and standards that are needed to protect the coast fall outside of the local authorities' mandate. Moreover, the *Town Planning Ordinance 18* carries a clause that a person who has incurred expenditure or whose property has been affected as a result of a development scheme may recover compensation from the relevant authority. There are exceptions to this clause, such as that compensation may not be claimed when costs are incurred as a result of provisions within development schemes that prohibit the use of land that may result in injury or loss of life. However, restrictions imposed as a result of environmental protection do not form part of the exceptions. Therefore, the local authorities may be reluctant to implement stringent measures for coastal protection, as they may fear that compensation may be claimed by, for example, businesses forced to relocate as a result of coastal protection policies.

The *Urban and Regional Planning Bill* has not been enacted yet. The Draft Bill provides for a hierarchy of structure plans (national, regional and urban) and the development of zoning schemes (NACOMA 2007a: 35). However, the Bill's value in promoting ICZM is limited by the fact that zoning schemes cannot extend to the marine areas unless these fall under the jurisdiction of the region or the municipal area (NACOMA 2007a: 99).

6.5.4. Institutional framework

a. Poor coordination between Line Ministries

The coastline is covered by protected areas and mining concessions, and most of it therefore falls under the jurisdiction of the Ministry of Environment and Tourism (MET), the Ministry of Fisheries and Marine Resources (MFMR) and the Ministry of Mines and Energy (MME). Each of the Line Ministries develops their own sectoral plan, according to the industries, natural resources and human activities they manage. However, the lack of consultation between each Ministry can lead to conflicting sectoral policies being issued, with detrimental consequences for the ecosystems located on the coast.

The haphazard coordination between Line Ministries means that the environment is perceived as a sectoral issue, a responsibility of the MET, and not an overarching consideration in policy formulation. Therefore, other ministries will often disregard issues pertaining to environmental degradation and conservation of biodiversity, as these are seen to be part of the MET's mandate.

There are no legally prescribed procedures, institutions, or mechanisms for consultation or coordination between ministries. Consultation will therefore take place on an *ad hoc* basis, with no formalised standard operating procedures (SOPs). SOPs contribute to the good running of a bureaucracy by encouraging best practice mechanisms. The lack of horizontal integration at the governmental level is thus a serious hindrance to the implementation of ICZM.

b. *Poor coordination between Local Authorities, Regional Councils and GRN*

In addition to fragmented horizontal integration, there is also poor vertical integration between the Government of the Republic of Namibia (GRN), the Regional Councils and the Local Authorities.

The Regional Councils are not directly involved in the management of the parks or in concession allocation. These responsibilities pertain to the relevant Line Ministry. For instance, the MME will be directly responsible for the allocation of mining concessions. Since the MME has to contend with businesses and vested interests, the inherent bias of the MME is toward mining interests, with no regard for the environment (since this is perceived as being the MET's mandate). Since Regional Councils are organised geographically, they have a better understanding and awareness of the biophysical and environmental characteristics of their coastline. Therefore, ICZM would greatly benefit if the protected areas would be devolved to the relevant regional authorities.

Responsibilities tend to be unclear and centralised within the sectoral Line Ministries. This overshadows the importance of tailoring sectoral policies to the geographical characteristics of each region. Regional Councils and Local Authorities would be more apt to engage in environmental protection since they have the knowledge of the carrying capacity of their coastline. The insufficient vertical integration between the different levels of governance is a serious concern for the effective implementation of ICZM. The ongoing decentralisation process should therefore be used as an opportunity to clearly define roles, mandates and a common vision for the management of coastal ecosystems.

6.5.5. *Resource management and policy planning*

a. *Overexploitation of resources*

The declining biomass and biodiversity of coastal and marine ecosystems is a direct result of unsustainable resource exploitation (commercial and recreation fishing) and over exploitation of resources (NACOMA 2007b: 3).

Underlying causes of inadequate resource management is the political pressure to allocate harvesting licenses. Indeed, high unemployment levels and poverty constitute pressing incentives for ignoring natural resource limitations. Research should be undertaken on how to diversify economic activities instead of relying solely on one specific livelihood.

The lack of knowledge of natural resource limitations is another underlying cause of the overexploitation of natural resources. Scientific information is often inaccessible at the regional level, within the Regional Councils and the communities they encompass. Dissemination of information and building capacity within Regional Council staff is of paramount importance.

Inadequate knowledge of the Benguela current system and poor law enforcement are also to blame for inadequate resource management. There is a shortage of skilled staff within the agencies responsible for managing natural resources. Therefore, the partnerships between the GRN, civil society and private sector need to be strengthened in order to create information-sharing platforms and encourage emulative linkages of 'best practice'. In addition, the remuneration packages and benefits offered to staff must be made for competitive so as to attract qualified people.

b. *No coordination between spatial development plans and sectoral plans*

Line ministries develop management plans in their respective mandates at the same time as Regional Councils develop Regional Development Plans (RDPs). These are often contradictory and conflicting, and the hierarchical bias tends to favour ministerial developmental plans. There is a lack of linkages between local, regional and national planning and management systems.

The coordination between different planning instruments needs to be improved. Moreover, the MET's involvement in regional planning needs to be increased in order to highlight the importance of conservation of protected areas.

Furthermore, regions often lack the capacity, agency and skilled staff to develop adequate environmental protection measures in their RDPs. An enabling framework for coordination between the different sectors is also lacking. This makes it difficult to reconcile conservation and development (such as mining, tourism and fishing activities). The legal framework needs to be strengthened so that RDPs become more participative and become the key instrument that all other land uses and sectoral planning refer to.

6.5.6. *Educational barriers and lack of participation*

a. *Poor awareness and knowledge of coastal values*

Insecurity in resource tenure means local communities may have limited access to the coast. Consequently, they have difficulty in attaching an intrinsic value to it. Research needs to be undertaken into the coast's biological and cultural assets and their potential as economic generators in order to engage stakeholders. Whereas assigning economic value to unquantifiable goods is arguably a difficult exercise, and may risk undermining the protection of qualitative values (such as aesthetics), it would serve to highlight the potential income households can derive from sustainable use of environmental resources. Scientific research should be complemented with indigenous peoples' traditional knowledge so as to attach importance to the coast's cultural and spiritual dimensions.

The Benguela Current Ecosystem is a sensitive ecosystem and is subject to intrinsic natural changes, which impact on natural resource availability. There is a general lack of knowledge within the local communities and governmental agencies on how to adapt to this variability in natural resource provision. Scientific research on this subject is needed to develop Regional Coastal Profiles and biodiversity mapping, which would in turn raise awareness on the fragility of the BCLME, and thus show how to sustainably extract resources from it.

b. Poor public participation and stakeholder engagement

There is insufficient public involvement on how the resources are used and benefit-sharing is inequitable. There is a poor level of public participation in biodiversity management planning. The inequitable pattern of benefit sharing has resulted in a detachment within the communities of conservation goals along the coast.

Therefore, the decentralisation process should be reinforced in order to allocate legal rights to communities to manage wildlife and other resources outside of or bordering protected areas. This would render sustainable resource management crucial to their survival.

Local involvement should be enhanced by using traditional knowledge in the use of and preservation of biodiversity. Mechanisms and incentives for conserving biotic resources outside of protected areas and in communal and private lands should be strengthened. The underlying goal is to enhance the perception that biodiversity can be an economic generator, by allowing communities the rights to reap the dividends of conservation activities.

The concession framework lacks transparency, and does not promote local community involvement. Policy-makers should examine the possibility that Regional Councils have the mandate to allocate permissions for operations within parks, in consultation with the MET.

The conservancies should be afforded additional rights to manage tourism in partnership with the MET and the private sector. This should be undertaken with a view that conservancies must be involved in the ownership, management and benefit from all natural resource-based activities (see 3.1).

6.6. Issues of Best Practice

Bottom-up governance

A barrier to effective management of the coastal ecosystems is the endemic inequity in Namibian society. Indeed, Namibia has a Gini⁹ coefficient of 0.6, one of the highest in the world (World Bank Country Brief). Impoverished households will be less engaged in coastal conservation, as their main priority is subsistence.

The implementation of an ecosystem approach for the management of Namibia's coastal resources would benefit from pro-poor practices, in order to raise the income of impoverished households. Pro-poor development initiatives would help create the impetus for transitioning from dependence on one environmental livelihood, to a strategy for wealth creation.

The rural poor often base their livelihood on environmental income, either from wild, uncultivated ecosystems (fisheries), or from agriculture. An improved management of the ecosystem would thus increase their productivity, which could lead to a higher income.

The *Nature Conservation Act* of 1996 devolved control over wildlife management and tourism to local communities. This has netted N\$14 million in income benefits, half in cash and half in dividends. Wildlife populations have recovered, benefiting tourism and bush meat harvest (WRI 2005).

The measures that need to be taken to achieve pro-poor and bottom-up governance are:

- a) Involvement of the poor in community decision-making.
- b) Initiatives must be initiated at a local scale, using the resources recognised as economically vital by the community.
- c) Management techniques should use a combination of modern and indigenous knowledge.
- d) Scientific research should be carried out in order to assess the potential of establishing a natural environmental resource base in a specific area.
- e) The natural environmental resource bases must be restored and replenished if they are severely depleted.
- f) Increase tenure security and rights to access resources for impoverished coastal communities.
- g) The communities must be represented in decision-making. Following the principle of subsidiarity, which states that decisions must be taken as closely as possible to the citizen; the decentralisation process must be encouraged.
- h) Improve procedural rights for coastal communities. Secure their access to information, courts, and their right to form active civil society groups.
- i) Increase distributional equity, in order to ensure that environmental income can be used for wealth creation.

Gender considerations

⁹ The Gini Coefficient is an indicator between 0 and 1 of distributional justice within a country. A score of 0 symbolises perfect equality, whereas a score of 1 represents a profoundly unequal society.

Environmental degradation and natural resource management are cross-cutting issues. However, women often lack ownership and even usufruct rights to the land (the right to enjoy the 'fruit', namely the profit reaped, from the land). The African Development Bank has found that Namibian women's ability to use land is jeopardised by harmful cultural practices such as discriminatory marriage customs and inheritance systems (ADB 2006: 51). Furthermore, even when women have the civil legal right to land, many lack the education, social or economic ability to legally enforce land claims.

The amended *Namibian Conservancies Act* of 1975 articulates a policy of community based natural resource management. There is over 4 million hectares of communal land under the control of conservancy management committees (ADB 2006: 52). Many of these ventures emphasise women's participation and leadership, with women accounting for about 25% of personnel on conservancy management committees.

Many Line Ministries tasked with ensuring access to land, agricultural services and water resources do not have a gender component in their policies, like the Ministry of Agriculture, Water and Forestry (MAWF), and the Ministry of Lands and Resettlement (MLR). The MLR considers resettlement a household issue, and therefore does not legislate in the private sphere. This leaves vulnerable women without the adequate legal protection within their own household. Furthermore, the African Development Bank has argued that 'MAWF still holds gender stereotyped views on women and the environment' (ADB 2006: 52).

Gender considerations are important in the light of establishing equity in the claim, use and management of coastal resources. Impoverished subsectors of the population are the first exposed to environmental risk, since their adaptive capacity is constrained. Vulnerabilities are often increased for impoverished women, who find themselves having to provide for a family while having to adapt to extreme weather events.

6.6.1. Adaptation/conservation strategies

The types of measures that are available to the Government of the Republic of Namibia fall under three categories, relative to the dimension of governance they attempt to improve.

6.6.2. Measures to improve the content of legislation and policies, and their enactment, implementation, monitoring and enforcement.

a. Legislate

Increase deterrents and penalties for environmental abuses, land degradation and overexploitation of resources.

- Enact the Urban and Regional Planning Bill. Amend it to include the establishment of zoning schemes for marine areas.
- Amend the Town Planning Ordinance 18 of 1954 to include environmental development schemes as exceptions to the compensation-claim clause.
- Increase the Ministry of Environment and Tourism (MET)'s involvement in regional planning schemes, to supervise the due diligence of the process and the consideration of environmental impacts and vulnerabilities.

- Afford conservancies additional rights to partake in the management of natural resource based activities and to reap economic dividends.

b. *Improve content of legislation*

- Increase linkages between different sectors (tourism, mining, and fishing) and environmental issues in the formulation of Regional Development Plans (RDPs), with a view to reconciling conservation and development.
- Strengthen mechanisms and incentives for the protection of biotic resources outside of protected areas and in communal and rural land.
- Improve procedural rights for coastal communities; improve resource tenure and access to land.
- Restore the natural environmental resource base if it is depleted, in order to promote pro-poor initiatives and develop community-based natural resource management.

c. *Improve instruments for policy planning*

- Develop environmental management techniques using a combination of modern technology and indigenous peoples' traditional knowledge.
- Develop Regional Coastal Profiles as well as an overarching Namibian one. Initiate biodiversity mapping for each of the four coastal regions.
- Establish a gender component within Line Ministries tasked of ensuring access to land, agricultural services and water resources, in order to increase equity in benefit-sharing.
- Conduct research on how to diversify economic activities in order to reduce the stress induced by the sole reliance on a particular environmental resource.
- Develop guidelines on how natural resources can be used sustainably through feasibility studies.

6.6.3. *Measures to improve the institutional framework, and increase horizontal and vertical integration.*

a. *Increase horizontal integration*

- Devise Standard Operating Procedures (SOPs) to formalise consultation between Line Ministries. SOPs devise a set of conventionalised behaviours or reactions to a certain event. For instance, one SOP will consist of stages for the consultative process. The aim of SOPs is to provide detailed, written instructions to achieve uniformity of the performance of a specific function.
- Increase the salience of environmental issues when devising sectoral plans by Line Ministries. This could be done by creating the post of 'Environmental Officer' within each line ministry that deals with coastal ecosystems (namely the

Ministry of Mines and Energy, the Ministry of Fisheries and Marine Resources, and to some extent the Ministry of Agriculture, Water and Forestry). The Environmental Officer would liaise with the MET and the relevant line ministry to ensure environmental diligence within sectoral plans.

b. Increase vertical integration

- Create an enabling framework for coordination between the sectoral development plans produced by Line Ministries, and between the Regional Development Plans (RDPs) produced by the Regional Councils.
- Revisit the role of RDPs and increase their legal power: RDPs should serve as the key policy planning instrument other sectoral plans refer to.
- Increase vertical linkages in the different governmental levels (national, regional and local) with a view to achieving subsidiarity.

c. Improve the institutional framework and pursue decentralisation

- Identify existing gaps and conflicting mandates in legislation.
- Pursue the ongoing decentralisation process, and use it as an avenue to clearly define roles, responsibilities and mandates.
- Devolve some power to the Regional Councils in the management of national parks and in concession allocation.

6.6.4. Increase public participation and build capacity

a. Build institutional capacity

- Build capacity within Regional Councils and train the staff on conservation.
- Develop monitoring and evaluation capacity in the Regional Councils.
- Increase the remuneration packages and benefits offered to Regional Council and Local Authority staff in order to attract qualified people.

b. Increase public involvement and decrease inequity

- Conduct an economic assessment of coastal assets and highlight their potential as economic generators and sources of livelihoods. Advertise this to local communities in particular so as to foster an attachment of value.
- Modify the concession framework to make it more equitable and transparent.
- Design strategies to increase the equitable flow of benefits from the sustainable use of ecosystems.

c. Improve knowledge and education

- Create information-sharing platforms between the different stakeholders in coastal management, namely between local communities, decision-makers, scientific communities, and the private sector. The information-sharing platforms should strive to create emulative linkages (whereby one agent emulates the 'best

practices' of another) between the different agents. This will necessitate the dissemination and advertising of 'best practice' measures and 'lessons learnt'.

- Initiate a public campaign of education and communication on the vulnerabilities and intrinsic natural changes of the Benguela Current System.
- Increase dissemination of information to all stakeholders, particularly local communities.

6.7. Conclusion

The approach taken by this report reconciled the ecosystem and governance dimensions of sea-level rise impacts on Namibia's coastline. The projected sea-level rise is anticipated to have various detrimental impacts on natural ecosystems. This in turn will impact the economic activities dependent on these ecosystem services. Climate change adaptation should be understood as a process, as due to the inherent uncertainty of future climatic impacts, the overarching goal for countries is 'to be adapting well, not well adapted' (UKCIP). There are specific adaptation strategies to deal with sea-level rise, which are of a practical and concrete nature. These are either engineering solutions (which seek to provide infrastructural protection such as sea-walls), or biological responses (such as the rehabilitation and conservation of estuaries and dune cordons to act as natural buffers). These proposed solutions are dealt with in detail by Cartwright, 2009. Notwithstanding the fact that there are instances where these specific and practical measures are needed to reduce immediate threats by sea-level rise, this should not overshadow the need for socio-institutional responses. Indeed, socio-institutional responses have the potential to mitigate against climate risk across the spectrum of climate change events.

Regarding sea level rise, adaptation strategies which are dynamic and have an increased range of coping responses in order to deal with climate variability are best managed according to the principles of Integrated Coastal Zone Management. ICZM aims to reconcile the economic, social, recreational and cultural objectives of the coastal zone, within the limits set by the carrying capacity of the coast. ICZM therefore takes a holistic and ecosystem approach to coastal zone management, and if successfully implemented, is amenable to coping with a wide range of climatic threats. This report was thus concerned with identifying the main barriers to ICZM, both within the environmental impacts dimension, and the governance dimension. The report investigated the nefarious effects sea level rise will have on natural systems, and the subsequent impact on coastal economic activities. The institutional, regulatory and policy framework was finally assessed with regards to its adequacy for achieving ICZM. A number of measures aimed at improving the content of legislation, the institutional framework, and building capacity were then proposed. Adaptation to climate change is an ongoing process, not a finality nor a goal. Nonetheless, policy-makers should strive to implement ICZM, following the holistic and ecosystem approach set out by this report. Unless conservation and development can be reconciled, other attempts at adaptation through infrastructural or engineering responses will not reduce in the long-term the impacts projected to occur.

7. Adaptation strategy options

By Anton Cartwright (Laquar Consultants, July 2009)

Identification of impacts of sea level rise and storm surges on biodiversity and the environment

7.1. Introduction

Climate change is affecting mean sea levels and the nature of storm activity along the Namibian coastlines in non-linear ways. This study suggests that changes in mean sea-level and storms will be adverse for Namibia. Future impacts are likely to be exacerbated by the loss of the coast's natural buffering capacity as a result of developments on sand dunes, disruption to the transport of sand by long shore currents and wind, the loss of wetlands and the manipulation of estuaries. The combination of a degraded coastal zone, extreme high tides, changes in sea-levels and altered frequency and intensity of storm events could result in significant economic losses. Significantly, the estimates of financial loss provided in this report assume no pre-emptive or adaptation activities aimed at reducing these costs. Climate change adaptation and especially early actions can significantly reduce the cost of climate change impacts. Whilst it is not possible to apply strict cost benefit analysis to adaptation decisions – the difficulty of choosing appropriate temporal and spatial scales for impacts, the inter-connectedness of impacts and benefits and the difficulty of evaluating ecosystem goods and services tend to make results implausible at best and misleading at worst – it is helpful for decision makers to consider the options at their disposal and to develop frameworks for sensible decision making (Van Ierland et al, 2007; Hallegate, 2008).

At that UNFCCC's Nairobi Conference of Parties (2006) it was acknowledged that climate change impacts were already being felt, and that regardless of the success of mitigation efforts, climate change and the ensuing consequences were set to get worse for at least two decades. The inevitability of change and resultant necessity of adaptation is particularly true for sea-level rise. The sea absorbs 80 per cent of the energy that is being added to the global atmosphere by anthropogenic climate change and due to the thermal expansion of the ocean will continue to expand long after atmospheric temperatures have ceased increasing. The resultant risks are, however, not inevitable and can be reduced by timely and well-constructed interventions. In the United Kingdom, for example, it is estimated that appropriate human and institutional responses to sea-level rise and flooding could reduce the associated cost of the phenomenon to that country by 27-fold relative to the business as usual scenario (Foresight, 2007).

This section of the Namibian sea-level rise report:

- Outlines current thinking with regards to climate change adaptation, internationally.
- Describes broad approaches for dealing with sea-level rise outside of Namibia.
- Introduces specific options for Namibia under the headings (1) “no-regrets” options, and (2) “additional” options which include physical, biological and socio-institutional options.
- Provides a framework for selecting appropriate sea-level rise adaptation measures.

7.2. **Climate change adaptation**

Climate adaptation efforts are being driven by the realization that future climate will require social and institutional changes that are unprecedented in terms of current climate variability. At the African Ministers Conference on the Environment held in June 2008 it was agreed that climate adaptation should not be seen as a “surrogate” for climate change mitigation. Rather climate adaptation was presented as a process that begins with understanding current vulnerability, involves creating capacity to support adaptation planning and implementation and requires learning from experience (UNEP, 2008). Effective climate adaptation will in many instances include mitigations measures.

There is a growing awareness that the complex and difficult to predict impacts produced by climate change render it impossible to “climate proof” a community or a country. Rather effective climate adaptation is an ongoing process that creates the scope to deal with a wide range of inherently difficult to predict climate contingencies. In the language of United Kingdom Climate Impacts Programme (UKCIP), “The aim is not to be well adapted, but adapting well” and some climate risk is inevitable regardless of adaptation or mitigation efforts. Climate adaptation is most effective when it influences decisions that would have had to be taken anyway, but which can be altered based on an understanding of climate change. Seen as a process, climate adaptation might bring a decision foreword (e.g. plans to install a flood barrage might be expedited due to climate change), result in different decisions to those that would have otherwise taken place (e.g. relocate the site of a planned power sub-station due to sea-level rise risks) or add new options that would not have been considered previously (e.g. invest in estuary rehabilitation instead of estuarine property development as a means of restoring the natural buffer to storm surges and back flooding of Swakop river at Swakopmund).

Climate change adaptation is acknowledged to impose both direct and indirect (via substitution and competitive effects) costs countries. The World Bank has suggested that \$10-\$40 billion per annum will be required globally for effective adaptation. Oxfam believe this figure to be in the order of \$50 billion per annum, while the Stern Review posited an estimate of 5 per cent of country GDP per annum. The burden of these costs is expected to be particularly severe on less developed countries.

In response the UNFCCC has initiated three funds (see Text Box 1) aimed at assisting countries in developing adaptation responses. As a UNFCCC signatory but also a “lower middle income country”, Namibia qualifies for two of these funds.

7.3. **Adapting to sea-level rise**

The risks generated by sea-level rise should be seen in the context of the suite of risks that climate change is likely to create for Namibia. It is the combination of climate change risks, and not sea-level rise on its own that is likely to be most damaging to Namibia. More importantly, a number of the potential responses to climate change risk, such as improved institutional coping capacity and better information, will mitigate risk across the spectrum of climate change events. For this reason responses to sea-level rise should be seen in the context of broader climate change adaptation efforts, but this does not remove the need for certain sea-level rise specific measures.

Until recently sea-level rise adaptation measures were focused on the small island states, many of which are highly exposed to the phenomenon. In the light of forecasts that suggest that sea-level rise could be an order of magnitude greater than originally thought by the end of the century, acknowledgement of concern over the problem has become more widespread. Concepts of best practice on sea-level rise are clear that the problem is best managed in accordance with the principles of integrated coastal zone management (ICZM) – a term that was coined during the 1992 Earth Summit in Rio de Janeiro. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives of the coastal zone within the limits set by natural dynamics. The approach that underpins ICZM is multi-disciplinary and iterative in the sense that it relies on ongoing information gathering, planning based on multiple objectives, decision making and monitoring. Failure to adopt an ICZM approach to managing sea-level rise risks, runs the threat of piecemeal responses and unforeseen consequences that amplify the mal-adaptation risks.

Some Namibian infrastructure already takes into account the impacts of variable climates. Houses are set back from flood lines along rivers, bridges and roads are constructed to withstand a wide range of temperatures and coastal development is set back from what are perceived to be the high water marks of sea-storm surges. Very little development, however, takes changes in climate trends into account. This is particularly true of Namibia's recent coastal property development which is based on past sea-level and storm and which does not consider the implications of projected sea-levels or storm surges. Perhaps some of the reasons for this are due to the innate uncertainty in future climate, and its impacts on sea-level rise, which makes it impossible to "predict and provide" clear planning directives or solutions to sea-level rise threats. It is not possible to use the output of a single climate model as an input for infrastructure design. This is not because climate models are poorly designed or rudimentary, but rather due to the innate uncertainty in climate systems. Even if climate models were perfectly accurate, uncertainty would not disappear; on the contrary, improved knowledge does not mean narrower projections and may imply greater uncertainty. As a result, the climate projections so often requested by decision makers are unlikely to be available soon. Instead of optimizing based on the climate conditions projected by models, future infrastructure should be designed with a directional climate change in mind and made robust to increasingly variable climate conditions. Typically this involves additional costs.

There is, equally, a growing global acknowledgement that many of the infrastructural approaches that have been used to prevent the sea from advancing in the past have proven costly to maintain

and sometimes ineffective. In addition, such efforts, by creating a false sense of security, often come at the expense of more effective social and institutional responses¹⁰. There is, however, considerable inertia in the built environment. Whilst “managed retreats” and a number of the non-infrastructure options that are discussed below are increasingly considered more prudent than the “engineering” solutions, the reality is that some settlements and infrastructure cannot be relocated or protected without additional infrastructure.

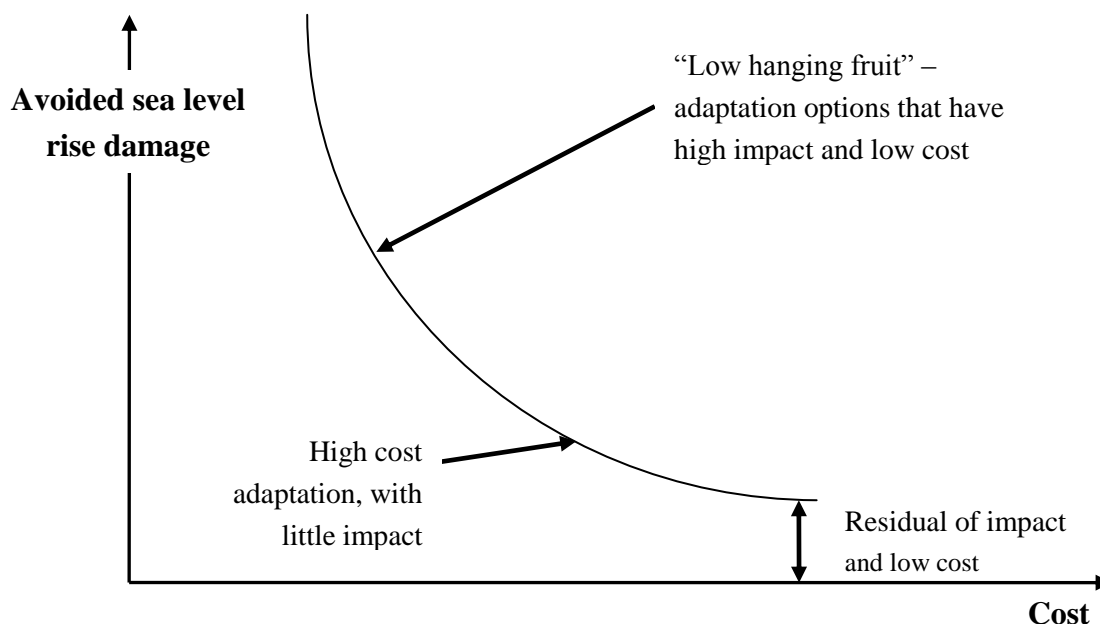


Figure 25: Avoided sea-level rise damage cost curve

With reference to the above figure, It is not possible to climate proof Namibia, or even to ensure total protection against all sea-level rise related impacts. The wider range of difficult to predict contingencies associated with sea-level rise under future climate change make it impossible to prevent all impacts. In general, the level of protection will increase with the resources allocated to the problem although priority should be given to the “low hanging fruit”, that is those options that deliver large reductions in sea-level rise risk at relatively low cost. Regardless of budget, some “residual” is likely to remain. This involves impacts that can not be adapted for. Typically, the residual imposes costs on the public sector and insurance industry in the form of pay-puts and disaster relief actions.

7.4. Options for Namibia

Broadly speaking the sea-level rise options for the Namibia can be classified into (1) “no regrets” options and (2) “additional” options proactively designed to counter sea-level rise and involving some form of trade-off or cost.¹¹ The “additional” options can themselves be classified into those that make financial sense because they save money (although the period over which money is saved is obviously critical to the analysis), and those that are necessary to save human life, reduce risk, or protect heritage sites or natural ecosystems but which simply cost money.

¹⁰ A review of coastal defences in Britain showed that in 38 % of locations they reduced risk while 18% of the time they actually increased flooding and erosion risk (Foresight, 2007).

¹¹ The word “additional” in this context is adopted from the climate mitigation discourse and refers to additional relative to business as usual

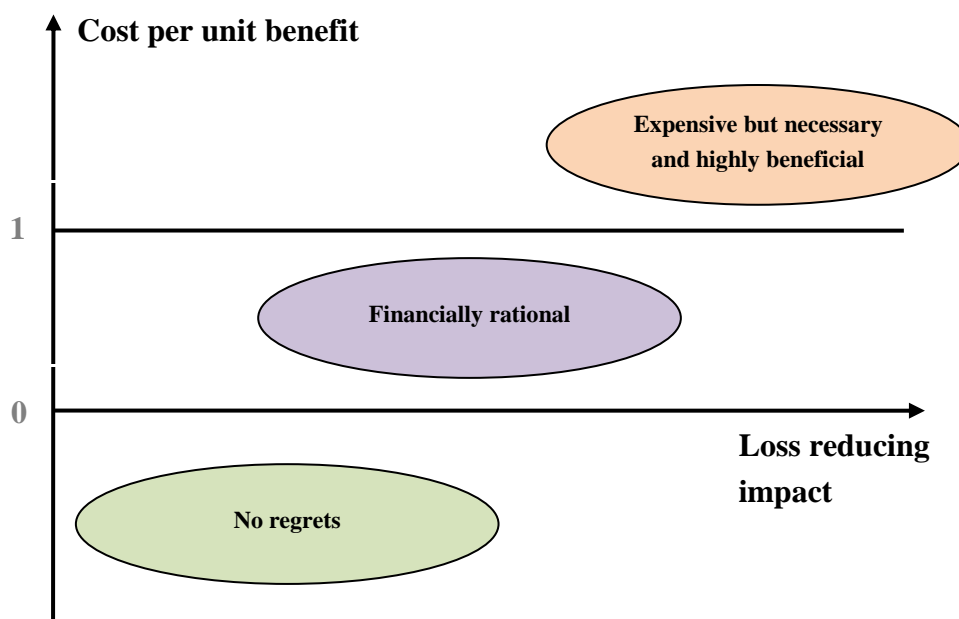


Figure 26: A highly stylised depiction of Namibia's adaptation options with regards to sea-level rise

“No regrets” options would be undertaken even if climate change were not happening and includes steps such as the enforcement of development restrictions in coastal zones and the alleviation of poverty; typically no regrets options do not require additional budget allocations over and above those that already exist. “Financially rational” options require a resource (budget) allocation but save more resources than they require. These options might include beach replenishment and vegetation buffers and certain well constructed sea walls. The final category of options, “Expensive but necessary” is subject to budget reallocations and a political commitment and includes items such as managed retreats, relocating infrastructure and the raising of port infrastructure.

7.4.1. “No regrets” approaches

“No regrets” actions are not directly related to sea-level rise, and would be worth pursuing even if the sea was not rising due to the systemic benefits that they deliver. Where no regrets steps are taken they assist in the ability to cope with sea-level rise. In most instances they do not require major amounts of additional funding, and do not rule out the possibility of the more targeted interventions such as infrastructure discussed below. In the context of sea-level rise, no regrets options available to Namibia include:

a. Do not further develop within the coastal buffer zone

Namibia has a coastal zone policy but in many instances this has been poorly enforced or compromised by historical planning rights. Preventing future development within a designated coastal buffer zone is a sure way of reducing the risk of sea-level rise. The vigour with which coastal development is prevented should take on new significance in the light of rising sea-levels in Namibia.

b. Do not further degrade wetland and estuaries.

Wetlands that are linked to the coast and estuaries serve as a natural buffer against sea-level rise and wave action in particular. Not only are they capable of absorbing large volumes of advancing water, and dissipating wave energy, they also create

natural refuge for species that would otherwise be adversely affected by sea-level rise changes. To reduce the size of estuaries, to remove the vegetation that they support or to curtail the flow of water within these estuaries in favour of new housing developments or infrastructure projects is to discount the role that these natural resources play in reducing sea-level rise risk. Similarly polluting these water resources undermines the ability of estuaries, lagoons and wetlands to support biodiversity in the face of other changes such as sea-level rise. The key “no-regrets” decision should be to at least not further disrupt these resources.

c. Do not further degrade dune cordons and sandbars

The sand dunes, and sand bar (at Pelican Point near Walvis Bay and at Henties Bay for example) that appear adjacent to the Namibian coast provide a natural defence against sea-level rise but are threatened by infrastructure that disrupts the flow of sand. As a matter of precaution, further disturbance of sand dunes should be prevented in order to retain the remaining protection that they offer.

d. Integrate sea-level rise scenarios into future planning decisions

The ability to relocate or adapt existing infrastructure is frequently limited, but the population growth in Namibian coastal cities, physical expansion and the growth of tourism requires ongoing construction of private and public infrastructure, including roads, energy sub-stations, storm water drains and housing settlements. The location and nature of planned infrastructure should draw on forecast sea-levels reported in this study. Failure to do this will result in damage that could have otherwise been avoided, and will impose unnecessary costs on individuals and on the country's infrastructure development. Whilst it is not, typically, possible to “climate proof” infrastructure the notion of “climate resilient development” does represent a legitimate goal.

e. Incorporate sea-level rise risks in disaster management strategies

The need for co-ordinated responses has become something of a cliché in the context of climate change and natural disaster management. It is however imperative that Namibian disaster relief units are kept abreast of information on how this risk is developing, and that they are given the opportunity to prepare for the management of this risk and its consequences. This is in keeping with a shift in the disaster management community towards the prevention of disasters rather than recovery from them (Thomalla et al., 2006).

f. Alleviate poverty and improve living conditions

Human vulnerability to sea-level rise is, to a certain extent, a function of the ability to mobilize away from the affected area and relocate to new areas, the ability to resettle after losing property or a house, the ability to re-invest after a major loss, the ability to seek shelter in structures capable of withstanding sea-level rise damage, access to the insurance market and the scope for drawing on a well resourced support network. Whilst affluence is not a guarantee against sea-level rise impacts, as with other climate change risks the poor are less able to afford flood insurance, live in less robust houses and are less able to afford repairs. As such the poor are disproportionately vulnerable

to sea-level rise and in this sense alleviating poverty and ensuring that people are able to reside in well built and well located houses will assist in creating the type of capacity required to reduce sea-level rise risks. Equally the ability to cope with sea-level rise (and other climate change risks) should feature in the poverty relief efforts of vulnerable communities.

7.4.2. “Additional” actions

Whilst the no-regrets options outlined above are uncontroversial in their scope and should be (and in many cases are already being) pursued as part of Namibia's ongoing development, adaptation to sea-level rise will also require targeted interventions aimed at managing specific aspects of the risk. These interventions involve new investment, new approaches and in most instances some form of trade-off or budget reallocation. These interventions are “additional” to business as usual and existing efforts to improve well-being and maintain the environment.

These options can be classified into physical, biological and institutional responses, and all of these options can be categorised into those that yield a benefit that exceeds the cost and those that do not contain a financial rationale but are nonetheless desirable. In many instances this last category is only financially irrational due to the failure to reflect the true value of environmental goods and services or the discounting of future risks.

7.4.3. Physical options

Hard engineering techniques - seawalls, groynes, detached breakwaters, and revetments – remain popular and account for over 70 per cent of the protected shoreline in Europe, for example.

a. Sea walls

Sea walls represent the most globally common form of coastal protection. Modern seawalls aim to destroy most of the incident energy, resulting in low reflected waves and much reduced turbulence. The use of “dolosse” or gabions to either construct or protect sea-walls from wave action is also considered good practice. In spite of this a UK study found that sea-walls around that country's coastline had a 38 per cent chance of improving the situation with regards to sea-level rise, but a simultaneous 18 per cent of unwittingly exacerbating it (Foresight, 2007). In addition sea-walls are often unsightly, and scar the very landscape they are seeking to protect.



Figure 27: An example of a modern seawall on the Isle of Wight, UK

Where properly planned sea-walls or the placement of dolosse may provide a last resort for protecting towns such as Swakopmund and places such as Walvis Bay in the instance of the Pelican Point sandspit being inundated and breached.

b. Groynes

Groynes are wooden, concrete or rock barriers or walls perpendicular to the sea. Groynes do not protect the beach against storm surges but can prevent long-shore drift and beach erosion. Groynes frequently create dangerous currents that endanger lives and carry sand offshore at the expense of the beach. Groynes require little maintenance and are effective in preventing long-shore drift. However as a counter to sea-level rise they tend to be ineffective if not detrimental.

c. Barrage and barriers

Barrages and barriers are used to protect settlements and ports from extreme high tides and storm surges. The famous barrages at Maeslantkering and on the Thames River protect the towns of Rotterdam and London respectively. The Thames Barrage offers protection against North Sea-tidal and storm surge in conjunction with high river levels, and is automatically triggered by forecasts projecting sea-levels 4.87 metres above the norm. The barrage, which was completed in 1984, is credited with having averted a number of sea-level rise catastrophes. Prior to 1990 the average number of barrage closures was 2 per annum. Since the 1990s the average number of barrage closures has increased to 4 per annum.

Barrages should be able to open during low risk periods to allow the passing of ships and marine life, and only deployed at high risk times. The problem, however, is that under future sea-level rise scenarios many barriers may have to remain closed most of the time. Barrages are costly to construct and maintain and pose the risk of blocking off what would otherwise be a natural buffer against storm surges (such as an estuary) and thereby displacing tide surges to adjacent areas. Installing and operating a barrage can only be considered when the value of the protected area is significant, and where detailed studies of the way in which the barrage will alter the storm surge have been completed. If fitted with turbines barrages can be used to generate energy from the passing tides.

d. Raising infrastructure

A fairly common response to sea-level rise involves simply raising the level of infrastructure. Walvis Bay Harbour, for example, would prove difficult to relocate, but could be raised or dredged in order to protect against sea-surges and inundation.

e. Revetments, rock armour, dolosse and gabions

Revetments, rock armour, dolosse and gabions are among the other physical infrastructure measures used to protect coastlines. They have a limited lifespan, are often damaged in storm conditions and reduce the recreational value of the beach. They are not common along Namibia's coastline and are not recommended for future protection of the coastline. "Dolosse" – a manufactured form of rock armour - are a South African invention applied internationally to dissipate wave energy. Dolosse are used with some effect at Cape Town Harbour in South Africa to protect reclaimed land and the harbour pier from direct wave action and might be used to similar affect at Walvis Bay or Luderitz.

f. Off-shore reefs

The use off-shore structures including tyres, sunken ships, dolosse and rocks (usually placed within or just behind the wave zone) has the potential to reduce the amount of energy with which waves impact upon and erode the shore and can contribute to wider beaches. To date most artificial reefs have been constructed to either enhance surfing conditions (Perth, Australia) or in attempt to promote marine life (Florida and South Carolina, United States), but such reefs do not have a good track-record. Reefs tend to alter the near-shore currents in difficult to predict ways, they affect sea-traffic and where they disintegrate (as the reef constructed from used tires in Fort Lauderdale, Florida, did) they can damage existing reefs and coastal vegetation. As Spieler (2002) points out, "Artificial reefs need to be designed to function for specific tasks, at specific sites for specific geographic areas". It is plausible that an off-shore reef would offer some protection to the Walvis Bay sandspit, for example, but the potential for creating unforeseen current and sand movement can not be ignored and this option would have to be thoroughly researched and trialled prior to implementation.



Figure 28: Concrete blocks used off the coast of Australia to create an artificial reef. The rocks have been designed to create refuge for sea-life

g. Beach and sandspit nourishment

Replenishing beaches, sand-spits and dunes with sand - a so called “soft engineering” solution - provides an alternative and often more successful physical approach to reducing sea-level rise risk. Sandy beaches are particularly vulnerable to erosion and retreat. One additional vertical unit of water can cause a 100 fold horizontal retreat (Douglas, et al. 2001) and losses of large sand volumes. Following a storm some sand is replaced naturally, but this can take time, is often interrupted by the following storm and typically results in a net sand loss. As Mather (2007) points out, “Where sand has been removed [by a storm], sand should be replaced”. Beach nourishment or replenishment involves importing sand and piling sand on top of the existing sand so as to raise the beach. The imported sand must be of a similar quality and particulate size to the existing beach material so it can integrate with the natural processes occurring there, and not inadvertently destabilise the beach. The same process can be followed to restore dune cordon at Henties Bay and Walvis Bay, for example. Where ongoing erosion prevents rehabilitation of the natural dune cordon, sand can be stored within geofabric bags angled back up the erosion slope so as to allow some wave run up over the sloping structure (Mather, 2007). Artificial dunes have a greater chance of succeeding when planted with dune vegetation for additional stability.

Necessary caveats with regards to beach nourishment relate to the sourcing the sand and ensuring sand is of the right texture. Where sand is sourced from adjacent zones those areas may become vulnerable, and where sand is dredged from off-shore it can adversely alter the bathymetry and contribute to greater erosion by increasing the energy with which waves approach the shore. Equally where sand is of a different size or texture it can end up destabilizing the beach. Beach nourishment is necessarily an ongoing process. Sand is required to be recharged every 1 to 10 years.

h. Water pumps

A number of cities (London in the United Kingdom, Maryland in the United States and Rotterdam in the Netherlands) actively pump sea water from draining systems during times of flooding. This highly reactive approach to managing sea-level rise is expensive and not recommended as anything more than a disaster relief activity.

The physical sea-defences described above are no longer considered “best practice” in efforts to manage sea-level rise (Hallegate, 2008), particularly given their propensity to result in unforeseen and adverse consequences, their relatively high cost and the fact that they do not provide absolute guarantees against inundation and storm surges. One of the main impacts of climate change in coastal zones is a dramatic increase in uncertainty, and the lack of flexibility inherent in many infrastructural approaches is poorly equipped to deal with this uncertainty. In spite of this infrastructural solutions continue to be used in specific contexts – most notably where it is prohibitively expensive to relocate infrastructure or settlements. In these instances sand and dune replenishment, where possible, tend to provide a more cost effective and sustainable barrier than hard engineering solutions. The key to all physical sea-defences is that they be based on an intimate understanding of near shore process including currents, dune mobility, species

migration and wave action. Over the past hundred years the limited knowledge of coastal sediment transport processes at the local government level has often resulted in inappropriate adaptation measures. In many cases, measures may have solved coastal erosion locally but have exacerbated coastal erosion problems at other locations or have generated other environmental or social problems. Failure to understand these elements of the near-shore environment will enhance the chance of physical interventions constituting mal-adaptation and amplifying risks.

i. Biological options

Biological responses to sea-level rise are seen as being more natural, less likely to produce adverse consequences and more cost effective than most physical options. The adoption of biological methods is based on the understanding that unperturbed coastal environments offered natural protection against sea-level rise in the past, but have been perturbed by human intervention thereby increasing the risk of future sea-level rise.

In tropical and sub-tropical regions this has seen efforts to restore mangroves that have been stripped by coastal developments or damaged by aquaculture activities (see Figure 29). The Namibian coast does not have tropical mangroves, but a number of alternative biological sea-level rise measures are available.



Figure 29: Established mangrove plantations on the coast of Fiji seek to restore degraded vegetation and coastal buffers against sea-level rise and storm surges

j. Dune cordons

Dunes, wetlands and sandbars form the natural coastal barrier at many of Namibia beaches – see Henties Bay and Walvis Bay in Brundrit's section of this report for example. Coastal wetlands are already under threat but will suffer additional impacts from saline intrusion when confronted with sea-level rise. This in turn will affect vegetation and flood buffering capacity. Coastal dunes are being threatened by development, restrictions to the movement of aeolian sand from the interior. Where Namibia's dunes become "cut-off" from inland sand sources, such as at Swakopmund, they require human management if they are to retain their function as a buffer to sea-

level rise. Successful precedents often include vegetation re-establishment and low-impact walk-ways for beachgoers. Where dunes are restored and dune grass is successfully established this vegetation is able to retain wind-swept sand and support the dune.

k. Estuary and wetland rehabilitation

Conserving and in some instances rehabilitating Namibia's estuaries and wetlands in order that natural vegetation returns to these resources and that they regain their full buffering capacity against storm surges provides a further biological option. Where successful, these areas will also offer refuge for species that would otherwise be adversely affected by sea-level rise. Achieving this would require more than a "no-regrets" prevention of the current degradation and encroachment into these resources. It would require a proactive investment in rehabilitation, an investment that could, in part, be justified by the reduced risk from sea-level rise that would ensue. Protecting the wetland areas to the south of Walvis Bay, for example, is seen as essential in maintaining the integrity of the sandspit that protects the bay from wave action.

l. Kelp beds

Kelp beds are a feature of the Namibian coastline. Kelp acts as a significant dissipater of wave energy. Although kelp is variably exposed and covered by low and high tides respectively it has the ability to grow with sea-level rise. Very little is known about changes in the extent of kelp off the South African and Namibian coast although anecdotal observations from aerial photographs in South Africa suggest that beds might be expanding (Howard Gold, pers. comms).

Kelp beds offer a partial solution to storm surges, and the factors affecting their extent should be better understood. In addition kelp washed up on beaches reduces wave energy, binds individual sand particles thereby contributing to beach structure, and fertilises dune vegetation. It is the practice on some of Namibia's beaches, for example, to remove kelp from beaches in order to maintain "clean" beaches for tourists and beach-goers. Unfortunately the removal of kelp in conjunction with the mechanical cleaning of beaches contributes to their destabilisation and vulnerability to erosion.

7.5. Institutional responses

Over the next decades, the main change global warming will bring us may not be the change in climate itself. It may be the uncertainty regarding future climate conditions, which was marginal during previous centuries and, therefore, was often neglected in decision-making. Currently uncertainty in future climate change is so large that it makes many traditional approaches to designing infrastructure and other long-lived investments inadequate. Acknowledgement of this has seen renewed focus on what are perceived to be more flexible behavioural and institutional approaches. Climate change adaptation is increasingly being seen as a social and institutional change process. Institutional responses do not preclude physical and biological responses; indeed the success of physical and biological approaches is on many ways dependent on a supportive institutional environment.

Most institutional responses to sea-level rise risk focus on increasing the capacity of people and the environment to cope with problem as a means of reducing risk. They also support the factoring in of climate change information into long-term decisions – decisions that are seen to be exposed to climate change impacts.

- **Vulnerability mapping:** Identifying vulnerable communities and locations represents the first and important step in any climate adaptation process. This study has identified vulnerable regions of the Namibian coastline and goes some way toward a vulnerability assessment.
- **Risk communication:** People with different risk aversions will be prepared to take on varying amounts of risk and respond to the threat of sea-level rise differently. In order to do this, however, they will require the best available information. Once vulnerable locations and communities have been identified it is incumbent on local authorities to communicate the extent of sea-level rise risk to local residents. There is no single “acceptable” level of sea-level rise risk. This is particularly critical for the private developments that are known to be exposed to high seas, and other possible developments that could be exercised due to poorly enforced coastal zone regulation or development rights issued imprudently in the past. Communicating the risk to these property owners and explaining the extent of private and public liability associated with the developments will not only shape the extent of future developments but prevent inappropriate demands or claims against the Namibian State in the event of a disaster.

Effective communication is also required in the wake of a sea-level rise event in order to prevent mal-adaptation risks. Piece-meal and opportunistic responses to sea-level rise have been identified as contributing to the problems incurred after the 2007 KwaZulu Natal, South Africa sea-level rise event for example. In part these actions were the result of uncertainty over who was responsible for the affected areas and private property owners’ uncertainty as to which sphere of government would assist them.

- **Apply legislation:** By adopting and enforcing coastal zone management legislation exposure to future sea-level rise risks can be significantly reduced. The most significant piece of legislation in this regard involves the formulation and application of a coastal buffer zone. In the context of sea-level rise risk coastal set-back zones are, “Frankly just good planning” (Mather, 2007) and can be justified against the required foregone development by their ability to prevent the costs of sea-level rise risk identified in this report. Where new information on the rate of sea-level rise, or the changed nature of storms shows that specific locations are more exposed than originally thought, the set-back zone should be adjusted accordingly. In some instances implementation of legislation and enforcement of a coastal buffer zone will necessitate a managed retreat from impacted areas (Pelican Point and sections of Walvis Bay for example) in order to manage risks. The emphasis in such processes should be on the effective communication and management of such relocations. Where coastal communities relocate the potential for new coastal marshes and wetlands is created and in many instances natural vegetation buffers return. In general coastal realignments represent a low cost option unless compensation and new accommodation has to be provided for affected people.
- **Research and monitoring:** Uncertainties with regards to the manner in which climate change is affecting, and will continue to affect, sea-levels and storm activities along Namibia’s coast remain. Some of this uncertainty is inherent, but some of it is due to a paucity of monitoring and

research. Sea level measurements are taken at Walvis Bay and Luderitz, but there are no official estimates of sea-level rise for Namibia in spite of the fact that we know sea-levels are rising at different rates at different locations. There is very little information on how the storms that affect the Namibian coastline might be altered by climate change. Better information on changing sea-levels and the relationship between climate change and future storms would assist Namibia in correctly prioritizing sea-level rise risks within the context of the various other risks that it is required to manage. In the case of Walvis Bay and the Pelican Point sandspit, a study should be performed of in-shore currents, local coastal topography and sand flows as a first step and prerequisite for future discussions on how to protect the sandspit and Walvis Bay from the impacts of sea level rise and storm surges. Monitoring and the ongoing collection of data and commissioning of research are consistent with the principles of ICZM, which should form the basis of all sea-level rise management. Ideally, in ICZM terms, research and data collection would be integrated with research on the changes in kelp-bed extent and changes in coastal bathymetry, all of which are known to be important to coastal impacts but are currently inadequately understood in Namibia.

- **Early warning systems:** The most damaging sea-level rise events are those involving extreme high tides coinciding with storm surges that are approaching land from a higher mean sea-level base. The three elements of a sea-level rise event, mean sea-level, tides and the weather that produces storms, change over very different timescales. They are also subject to very differing levels of predictability. Mean sea-level changes are very difficult to predict due to the inherent uncertainties surrounding climate change, but these changes tend to take place gradually and can be recorded. Tidal flux is entirely predictable, whilst coastal weather and associated swell height can be predicted with some accuracy over a 3 to 5 day period. By combining the information from the predictable elements of a sea-level rise event it is possible to create a reasonably robust system capable of giving coastal inhabitants and businesses 3 days warning of sea-level rise events. Warning allows measures to be taken that can reduce risk such as outward migration, the clearing of storm water drains and the sandbagging of properties. The early warning system could be outsourced by the Namibian Government or could be operated in-house NOAA Wavewatch III <http://polar.ncep.gov/waves/viewer.shtml> to obtain specific wave heights, wind speed and direction and combine this with the available tide record.
- **Insurance market correction:** The insurance markets depend on correct assessments of long-term risks, and yet much of the insurance extended to coastal properties in Namibia does not factor the risk of sea-level changes into its assessment (Le Roux, pers. comm.¹²). The maximum sea-level recorded at Walvis Bay (LLD = 122cm) and Luderitz (LLD = 114 cm) is assumed to have a return period of just under 200 years, but this is based on historical occurrence and not projections of rising sea-levels or altered storm patterns. By providing the insurance industry with publicly generated information on the risk of sea-level rise, it is possible that insurance premiums for coastal developments will be raised. This would be adverse for the people and companies seeking to be insured, but in the long run it would guide investment and settlement

¹² Andrew le Roux is an actuary with Old Mutual Insurance and was previously located in Windhoek. He was consulted for this assignment

in these areas and reduce the costs of the liability, some of which is a public liability, in these areas.¹³

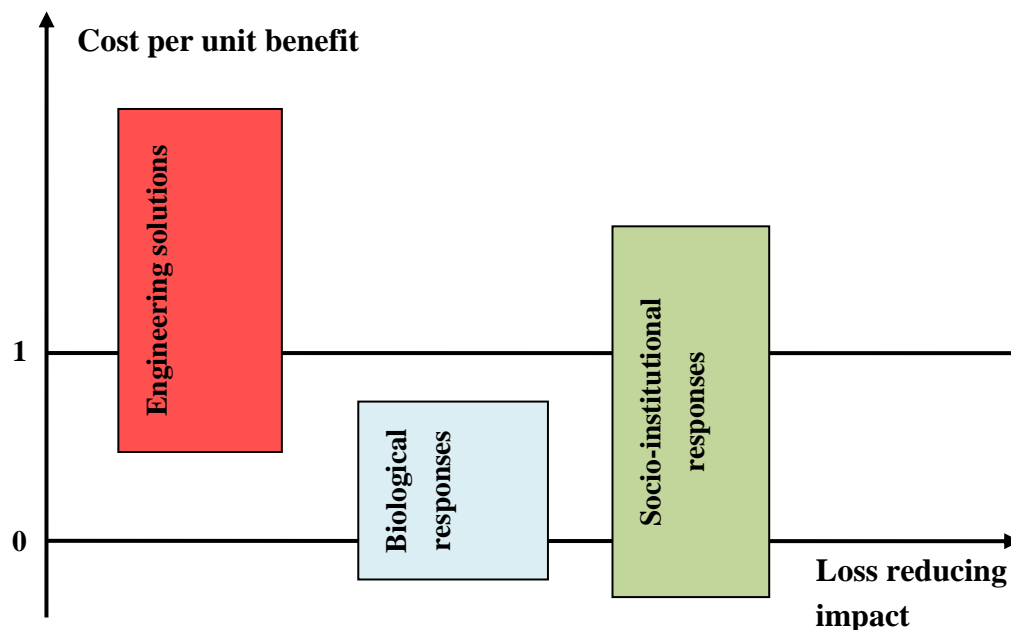


Figure 30: Stylized depiction of the potential cost and impact respective engineering (infrastructure), biological and socio-institutional responses to sea-level rise

It should be noted that the categories are not necessarily distinct from each other. In general infrastructural responses tend to be expenses, difficult to implement well and have a high propensity to yield unforeseen adverse consequences. Where well constructed, however, they can provide high levels of protection. Biological and socio-institutional responses can be cost-effective but are also complicated to mobilise. These approaches do tend to be safer and can yield a high degree of protection.

¹³ Namibia is not alone in this predicament. In the US, flood insurance maps do not inform current or prospective coastal property owners of erosion risks (Heinz Center, 2000)

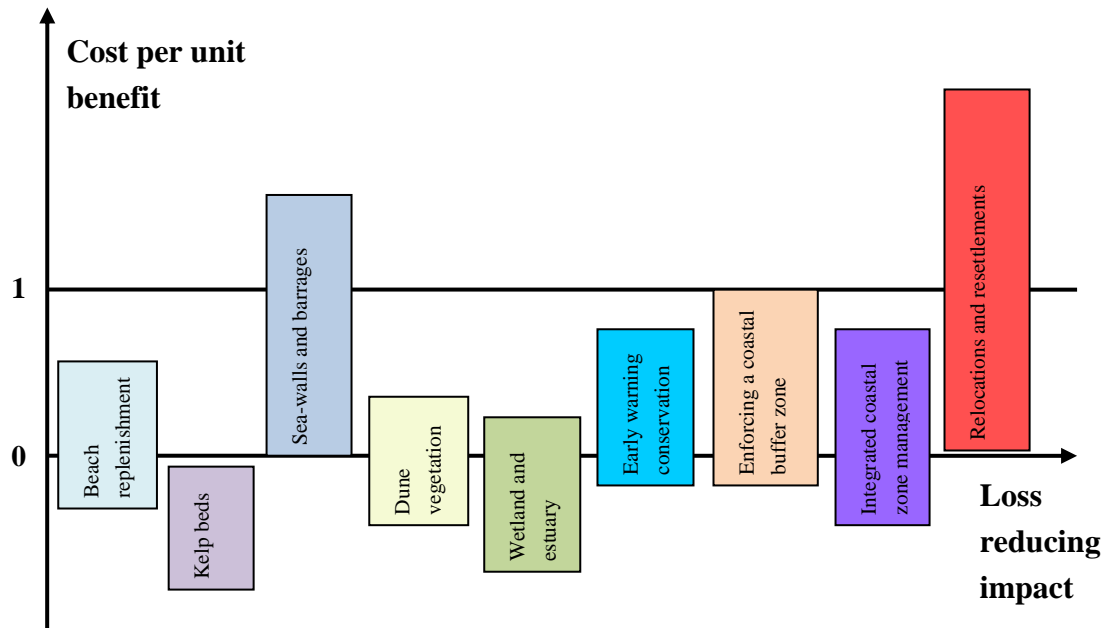


Figure 31: A stylized depiction of Namibia’s sea-level rise adaptation options

Options with a high “loss reducing impact” and low “cost per unit benefit” should be prioritised. Importantly however all costs and benefits (not simply financial costs) should be imputed into the ranking of options, and combinations of options should be favoured over discrete responses. The illustration is, in this sense, a decision support tool and not a solution to sea-level rise. It is important to note that those options that are “financially rational” (have a cost per unit benefit of less than 1) still require up-front capital and may take some time to generate their return. Equally important is the notion that desirable some options will simply require budget expenditure and can not be expected to cover their costs. This is especially the case of options that protect ecosystem goods and services, biodiversity and human life all of which can be difficult to value.

7.6. Selecting the most appropriate adaptation measure

The “correct” response to sea-level rise will necessarily be site specific and dependent on geological, social, financial and ecological conditions in the affected areas. This report has identified a number of options available for the management of sea-level rise risk, and suggested that the principle of ICZM – iterative data collection, planning, decision making and monitoring - should be used to guide whatever adaptation responses are implemented. The more difficult task involves deciding which measures to apply. It is not the role of this study to stipulate the Namibia’s responses to sea-level rise. On the contrary, the point is made that is not possible to “predicts and provide” sea-level rise solutions. The study is well placed to identify the types of considerations that should be taken into account in the decisions that will constitute the appropriate adaptation measures. Critically it should be acknowledged that sea-level rise solutions in Namibia will be required to cope with a wide range of climate conditions and this range is itself inherently uncertain. Rather than seek the “best” solution, it is more appropriate to look for the “most robust” option (or combination of options), where robustness is determined by insensitivity to future climate conditions (Hallegate, 2008).

7.6.1. Cost and benefits

Climate change adaptation will impose costs, but the most costly responses to sea-level rise are not necessarily the most effective. Whilst investment in adaptation measures should be justified against the cost of impacts reported in this study, those options that deliver the greatest possibility of protection for the least cost should be deployed first. The use of cost benefit should, however, be accompanied by the caveat that this approach can also be limited and lead to the misallocation of resources. Ideally cost benefit assessments would include both direct and indirect costs as well as mal-adaptation costs, and be used alongside qualitative assessments as a decision support process.

7.6.2. Foregone options

A key consideration in all sea-level rise efforts involves the extent to which a particular option forecloses on the potential alternative options. If climate change adaptation is to be an iterative socio-institutional learning process (SEI, 2008) in which neither the nature of impacts nor the efficacy of responses is perfectly known, then options that permit alternative or additional measures to be taken should, all other things being equal, be favoured over options that rule out alternatives. Early warning systems do not, for example, rule out the potential for constructing a sea-wall or orchestrating a retreat, but the construction of a sea-wall may make a managed retreat less likely in the short term, and in most instances will rule out options such as beach replenishment or vegetation buffers. In this instance the early warning system is more attractive than the sea-wall. Similarly beach replenishment can be reversed or used in conjunction with insurance market measures or better communication, but once a retreat has taken place and infrastructure foregone, it may prove very difficult to recover an area.

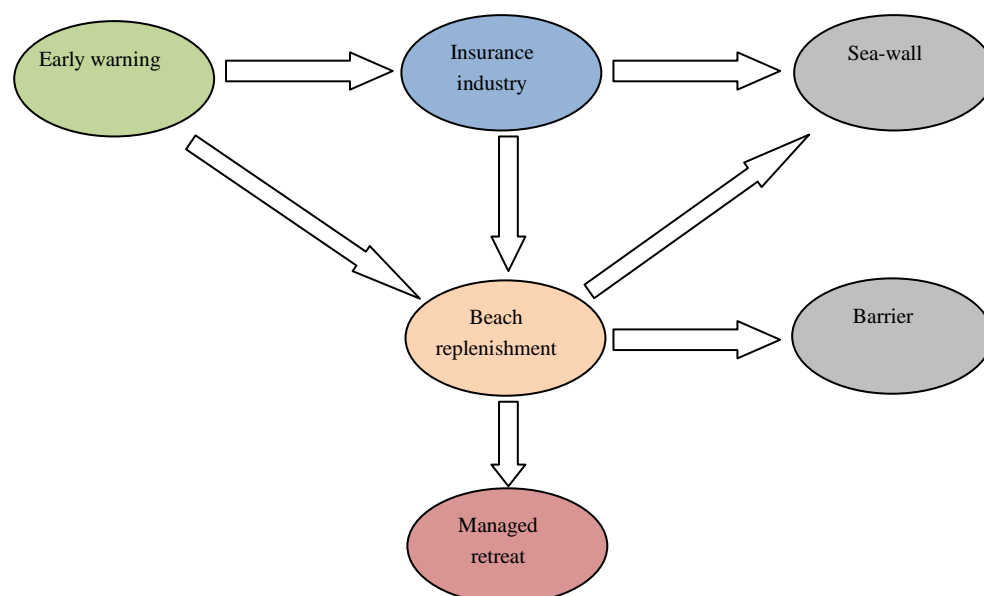


Figure 32: A hypothetical climate adaptation decision-tree, showing the pathway of potential measures and the foreclosure of other measures by certain decisions

7.6.3. Combined options reduce the most risk

Sea-level rise imposes multifaceted risks that impact via different mechanisms over very different spatial and temporal scales. Very few single interventions (with the possible exception of managed retreat) are able to address all of the risks generated by sea-level rise. For this reason combinations of responses tend to be more effective, and sometimes cheaper than any single option (Foresight, 2007; Von Ierland, 2007). The appropriate combination of adaptation measures will differ depending on circumstances, but as a general approach combined solution should be sought over single interventions.

7.6.4. Potential for unforeseen consequences

A number of responses to sea-level rise run the risk of having unforeseen and perverse impacts. Options such as sea-walls barrages and rock armour that have a track-record of unforeseen impacts should be deployed with more caution than those such as dune stabilisation and early warning systems that do not. Particularly where the coastal features such as sediment deposit, storm frequency, bathymetry and biodiversity are not well understood, preference should be given to those options that are less likely to produce unforeseen consequences.

7.6.5. Capacity to implement

The best sea-level rise options combine integrated institutional responses. Social and institutional capacity is a function of social cohesion and effective governance. Where this is not present in a particular location, overly ambitious institutional responses may prove inappropriate.

The following Table 5 provides a summary of the adaptation options with comments on costs, benefits, potential adverse consequences and suitability for Namibia.

Option	Cost	Benefits	Potential for adverse consequences	Suitability in Namibia
Effective communication campaigns	Potentially very low cost.	Many benefits. Allows individuals to make own decisions with regards to risk.	Limited. May induce over-reaction from public. Could affect a region's competitiveness.	Highly suitable and does not negate the possibility of other measures.
Apply Legislation	Low	Use of laws and zoning regulations to reduce property and infrastructure development in environmentally sensitive areas and areas at risk of being impacted by sea level rise and increasing storm surges	Potentially, the methods for determining the land areas not to be developed due to risks of sea level rise and increasing storm surges would be based on uncertain models for climate change and sea level rise.	Highly suitable
Research and monitoring	Low	Detailed and practical information about the status of sea level rise and storm surges along Namibia's coast, and about site specific conditions such as the Pelican Point sandspit in WB	Limited	Highly suitable

Option	Cost	Benefits	Potential for adverse consequences	Suitability in Namibia
Vulnerability Mapping	Low	Increased knowledge of priority areas that are most vulnerable to sea level rise and storm surges	Accuracy of mapping is dependent on uncertain models for climate change and sea level rise	Highly suitable
Insurance market correction	Very low cost provided research is available.	Many benefits. Over long term can be expected to guide investment in coastal areas.	May result in higher insurance premiums and higher number of uninsured in which case it will burden the poor most. Uninsured may fall back on government support in times of disaster.	Highly suitable as long as effectively managed.
Early warning system	Can be very low cost.	Multiple benefits. Allow individuals to respond in line with their risk aversion and exposure. Most effective where options for risk reduction exist e.g. evacuation plan, barrage.	Low, but requires public credibility and clear understanding as to the appropriate response.	Highly suitable. Can be used in conjunction with other options.
Wetland and estuary rehabilitation	Can be low cost, provided wetlands are not built upon..	Limited impact with regards to sea-level rise, but multiple biodiversity and aesthetic benefits.	Low.	Highly suitable as a first step wherever wetlands and estuaries exist. Does not forego the option of more drastic measures at a later stage.
Beach and dune replenishment	Moderate, but ongoing. US\$ 1,200-1,500 per mete of beach)	Can provide highly effective defence.	Low provided sand is suitable in size and harvested from an appropriate source. Requires intimate understanding of near-shore currents and wave action.	Suitable for many sandy beaches along Namibian coastline, including the Pelican Point sandspit.
Beach face drainage	Reported to be comparable to beach replenishment.	Results in sand accretion, has achieved satisfactory results in Europe.	May result in saline encroachment into groundwater. High energy costs.	Unproven in the Namibia but may assist in protecting sandy beaches. Not recommended as a first option.
Raising infrastructure	Expensive especially were supporting infrastructure has to be raised to remain aligned. Costs are roughly \$100 million to raise New Orleans levees one foot above normal (Leatherman and Burkett, 2002).	Allows continued functioning of infrastructure and infrastructure networks such as ports and roads.	May be difficult to know how high to raise infrastructure - "how safe is safe enough". Raising roads creates problems under bridges where clearance becomes inadequate.	Suitable to protect ports and certain roads and weirs.

Option	Cost	Benefits	Potential for adverse consequences	Suitability in Namibia
Sea-walls	High and ongoing maintenance costs. R 3,000 – R 30,000 per metre.	Can provide effective protection from wave action in particular. Allows continued occupation and business. Walls can be raised and fortified incrementally as the sea rises.	High. Walls can be overtopped, can displace wave energy and cause heightened erosion. Walls create a false sense of security. Restrict public access.	Can be suitable to protect existing infrastructure that is difficult to relocate. Not recommended as part of new planning measures. Can be employed at the base of cliffs and possibly at the Pelican Point sandspit.
Barrages and barriers	Very expensive	Can provide effective protection for settlements and properties that can be easily barricaded e.g. those based on estuaries.	High. In the future barrages may be closed most of the time which will damage ecosystem and restrict movement.	May be suitable in the future at lagoon and estuary sites, after other options have been exhausted.
Rock armour and gabions	Depends on availability of rock. Can be low cost where local rock is available.	Can be used to stabilise sea-cliffs.	Very high. Often increases erosion, unsightly. Rocks in mesh cages frequently break free from their cages.	Generally not suitable, although gabions may be considered amongst the possible options to protect the Pelican Point sandspit.
Groynes	Moderate. An unverified web source cites the cost of groynes to US\$ 90 per metre, although clearly some groynes are more expensive than this.	Limited benefits for storm surges and changes in mean sea-level	High. Alters current and sand circulation. Unsightly.	Not suitable.
Managed retreat	Compensation to property owners, lost public infrastructure, loss of real estate. May result in public liability and can involve protracted negotiation.	The most reliable and long-term solution to sea-level rise. May create new wetland and estuarine habitats.	Relocation of people and infrastructure can generate new social and environmental risks. Foregoes the option of less dramatic measures. Knowing how far to retreat can be difficult.	An option that may be considered in the future, especially if the extreme-impact scenarios associated with the melting of polar ice caps should be realised.

Table 5: relative cost, benefits, potential for unforeseen consequences and suitability of the adaptation options

8. Annex I – Sources and procedures

8.1. Citations and other sources of background information and statistics:

Section 6

IPCC (2007). Climate Change 2007: the physical basis, summary for policy makers. Contribution from Work Group 1, Fourth Assessment Report of the Intergovernmental Panel for Climate Change. Cambridge United Kingdom.

IPCC AR4 Synthesis Report: Summary for Policy Makers (Nov 2007). Intergovernmental Panel on Climate Change, Fourth Assessment Report.

www.ipcc.ch/ipccreports/ar4-syr

Rossouw J (1989). Design Waves for the South African Coastline. PhD thesis, University of Stellenbosch, South Africa, March 2009.

South African Tide Tables (Annual publication). Hydrographer, South African Navy.

www.sanho.co.za/tides/ The historic archive of sea levels at the Permanent Service for Mean Sea Level www.pol.ac.uk/psmsl/

The Stern Review: The Economics of Climate Change (2006), United Kingdom Government.

UNFCCC (2002): The Initial National Communication from Namibia to the United Nations Framework Convention on climate Change, 154pp.

World Bank Policy Research Working Paper 4136, Feb 2007. Impact of sea level rise on developing countries; a comparative study. S Dasgupta et al.

Journal articles

GB Brundrit (1995). Trends of southern African sea level: statistical analysis and interpretation. South African Journal of Marine Science 16: 9-17.

JA Church et al (2004). Estimates of the regional distribution of sea level rise over the 1950-2000 period. Journal of Climate, 17: 2609-2624.

P Hughes, GB Brundrit and S Searson (1992). The vulnerability of Walvis Bay to rising sea levels. Journal of Coastal Research 8(4) 868-881.

R Nicholls and R Tol (2006). Impacts and responses to sea level rise: a global analysis of the SRES scenarios over the 21st century. Philosophical Transactions of the Royal Society, A364: 1073-1095.

S Searson and GB Brundrit (1995). Extreme high sea levels around the coast of southern Africa. *South African Journal of Science*, 91, 579-588.

A.M. Smith, L.A. Guastella, S.C. Bundy and AA Mather (2007). Combined marine storm and Saros spring high tide erosion events along the KwaZulu-Natal coast in March 2007. *South African Journal of Science* 103, 274-276.

AK Theron (2007). Analysis of Potential Coastal Zone Climate Change Impacts and Possible Response Options in the Southern African Region. Proceedings IPCC TGICA Conference: Integrating Analysis of Regional Climate Change and Response Options; Nadi, Fiji, June, 2007. p 269-284

R Tol et al (2006). Adaptation to five metres of sea level rise. *Journal of Risk Research* 9(5): 467-482.

PL Woodworth, A Aman and T Aarup (2007). Sea level monitoring in Africa. *African Journal of Marine Science* 29(3) 321-330.

Section 7

<http://www.nacoma.org.na>

<http://www.dlist-benguela.org>

<http://www.nepru.org.na>

en.wikipedia.org/wiki

<https://www.cia.gov/library/publications/the-world-factbook>

<http://earthtrends.wri.org/text/population-health/country-profile-129.html>

Section 8

African Development Bank, 2006, Gender Country Profile: Namibia.

Bakun, A. And Weeks, S. J., 2004. Greenhouse gas buildup, sardines, submarine eruptions and the possibility of abrupt degradation of intense marine upwelling systems. *Ecol. Lett.*, 7, 1015-1023.

Batty, M., Tjipute, M., Shapi, M., Sowman, M., Cardoso, P., and P. Fielding, 2005. Overview and analysis of social, economic and fisheries information to promote artisanal fisheries management in the BCLME region – Namibia. Final report and recommendation (Namibia).

Bird E., 1993. *Submerging Coasts. The Effects of a Rising Sea Level on Coastal Environments*. John Wiley and Sons, Sussex.

BirdLife International, 2009. Damara Tern. www.birdlife.org. 15 July 2009.

Brundrit, G. B., 2009. A sea level rise assessment for the coast of Namibia. A contribution to 9042ALV-UNCCC Strategies to Cope with Sea Level Rise in Coastal Towns and Wetlands for UNFCCC Consulting Services Africa.

Cartwright, A., Brundrit, G. & L. Fairhurst. 2008. Global Climate Change and Adaptation- A Sea Level Rise and Risk Assessment. Prepared for: The City of Cape Town Environment Resource Management Department. Prepared by LaquaR Consultants CC.

COM (2000) 547 final, Communication from the Commission to the Council and the European Parliament on Integrated Coastal Zone Management: A Strategy for Europe. Available <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0547:FIN:EN:PDF>.

The Constitution of the Republic of Namibia, 1990. Available at <http://www.orusovo.com/namcon/>

Dasgupta, S., Lapalante, B., Murray, S., and D. Wheeler, 2009. Sea-Level Rise and Storm Surges. A Comparative Analysis of Impacts in Developing Countries. The World Bank Development Research Group, Environment and Energy Team.

Douglas, B. C., Kearney, N. S., & S. P. Leatherman. 2001. Sea Level Rise: History and Consequences. *International Geophysics Series 75*. Academic Press, Florida

EcoAfrica Environmental Consultants. 2009. Green Paper: Towards a Coastal Policy for Namibia. Ministry of Environment and Tourism- Namibian Coast Conservation and management (NACOMA).

Goss-Custard, J. D., McGroarty, S., Kirby, R. 1990. Inshore birds of the soft coasts and sea level rise in Beukema, J. J. *et.al.* (ed), 1990. Expected effects if climatic change on marine coastal ecosystems. *Developments in hydro biology 57*.

Graham, M.H., 1997. 'Factors determining the upper limit of giant kelp *Macrocystis pyrifera* Agardh, along the Monterey peninsula, central California, USA'. *J. Exp. Mar. Bio. Ecol.*, 218, 127-149.

Grossman, E. & S. Johnson. 2008. USGS Workshop on Sea-Level-Rise Impacts. Available at <http://www.soundwaves.usgs.gov> [accessed 23 February 2009]

Harley, C. D.G., A. R. Huges, K. M. hultgren, B. G. Miner, C. J. B. Sorte., C.S. Thornber, L. F. Rodriguez, L. Tomanek and S. L. Williams, 2006. The impacts of climate change in coastal marine systems. *Ecology letters*. **9**: 228-241.

Henrik, S., Bloch, R., Stuer-Lauridsen, F. and D. Uushona, 2009. Strategic Environmental Assessment (SEA) for the coastal areas of the Karas and Hardap Regions. NACOMA.

Hughes, P., G.B. Brundrit and S. Searson, 1992. 'The Vulnerability of Walvis Bay to Rising Sea Levels'. *Journal of Coastal Research*, 8:4, 868-881.

LAB, 2008. Walvis Bay Biodiversity Report. Local Action for Biodiversity, an ICLEI Initiative: Enhancing Urban Nature through a global network of Local Governments.

INGC. 2009. Synthesis report. INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [van Logchem B and Brito R (ed.)]. INGC, Mozambique.

IPCC 2001. *Climate Change 2001, Synthesis Report. A contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, UK.

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning,

Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IUCN, 2009. The red list category: Near Threatened. www.iucnredlist.org. *Sterna balaenarum*. 15 July 2009.

Jallow, B. P., Barrow, M. K., & S. P. Leatherman. 1996. Vulnerability of the coastal zone of The Gambia to sea level rise and development of response strategies and adaptation options. *Climate Research* **6**: 165-177.

Mukheibir, P. And G. Ziervogel, 2006. Framework for Adaptation to Climate Change in the City of Cape Town (FAC4T). Report to the City of Cape Town: Environmental Resource Management.

NACOMA, 2009. Walk on our coastline. www.nacoma.org.na/Our_Coast/WalkOnOurCoastline.htm #Omaruru. 2 July 2009.

NACOMA 2007a, Review of existing institutional mandates, policies and laws relating to coastal management, and proposals for change - Study Report.

NACOMA 2007b, Review of existing institutional mandates, policies and laws relating to coastal management, and proposals for change – Issues and Options Paper.

Nicholls, R.G., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden & C.D. Woodroffe, 2007: Coastal Systems and Low-Lying Areas, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 315-356.

Nicholls, R.J., Hoozemans, F.M.J., & M. Marchand. 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. *Global Environmental Change* **9**: S69-S87

Nicholls, R. J. & S. P. Leatherman. 1994. Global sea-level rise. In: Strzepek, K. & J. B. Smith (eds) *As climate changes: Potential Impacts and Implications*. Cambridge University Press, Cambridge.

Skilleter, G.A., A.J. Underwood, A.C. Jackson, 2008. Ecological consequences of global warming: predicting the effects on biodiversity on intertidal assemblages on the east coast of Australia. Centre for Research on Ecological Impacts of coastal cities (EICC). Available at <http://www.eicc.bio.usyd.edu.au>.

Theron, A.K. & M. Rossouw. (undated) Analysis of potential coastal zone climate change impacts and possible response options in the southern African region. Coastal Climate Change Impacts of Southern. Available at <http://www.csir.co.za> [accessed 27 February 2009]

Titus, J. 1989. The Causes and Effects of Sea Level Rise. In: Abrahamson, D. E. (ed) *The Challenge of Global Warming*. Island Press, Washington DC, pp 161-195.

UNFCCC. 2002. The Initial National Communication from Namibia to the United Nations Framework Convention on climate Change, 154pp.

Walvis Bay municipality, 2009. Walvis Bay – Your Oasis of Opportunities.
www.walvisbay.org.na 2009-06-22

Walvis Bay Biodiversity Report, 2008. Local Action for biodiversity (LAB), ICLEI Africa Secretariat, Vlaeberg, South Africa.

World Bank Country Brief, Namibia.

World Resources Institute, 2005, The Wealth of the Poor: Managing Ecosystems to Fight Poverty.

8.2. Entities contacted to obtain town planning (cadastral and land use):

- Hentiesbay town council (contacted telephonically): The council did not have any relevant, formal planning in their records. CSA was referred to the Office of the Surveyor General in Windhoek.
- Swakopmund municipality (contacted telephonically, physically visited prior to stakeholder interactions): The municipality provided the requested information in good time.
- Walvisbay municipality (contacted telephonically and via email, physically visited prior to stakeholder interactions): The municipality provided the requested information, subsequent to a brief meeting in Walvisbay with the council, in support of our request for information.
- Lüderitz town council (contacted telephonically and via email): Due to the difficulty in determining the responsible persons at the town council CSA referred to the Office of the Surveyor General in Windhoek.
- Office of the Surveyor General (contacted telephonically and via email, physically visited): The Surveyor General's office had comprehensive cadastral planning for all the coastal towns, but unfortunately no contour or land use mapping. Some topographical maps were obtained for the purpose of estimating global impacts in the coastline.
- Urban Dynamics Africa (contacted telephonically and via email): Urban Dynamics provided a significant portion of the required information for Walvisbay, Swakopmund and Hentiesbay.
- Stubenrauch Planning Consultants (contacted telephonically and via email): Stubenrauch Consultants were unable to assist in the acquisition of detailed planning.
- Strydom and Associates (contacted telephonically and via email): Strydom and Associates were unable to assist in the acquisition of detailed planning.

8.3. Entities contacted to obtain infrastructure planning (bulk municipal service):

- Urban Dynamics Africa: UDA was able to provide basic municipal services layouts for Walvisbay.
- Swakopmund municipality: The municipality did not provide further information.
- Walvisbay municipality: The municipality provided information for key infrastructure.

8.4. Entities contacted to obtain contour mapping:

- Urban Dynamics Africa: UDA was able to provide basic contour mapping for Swakopmund.
- Swakopmund municipality: The municipality provided contour information.
- The Office of the Surveyor General was approached for contour / level information for the entire coast or at least around the coastal municipalities. The Surveyor's office indicated that a LIDAR survey had been completed, but that the results were not available to the general public at the time of compiling this report.

8.5. Entities contacted to obtain environmental mapping:

- NACOMA (Namibia Coast Conservation and Management Project, contacted telephonically and via email): Nacoma was able to provide a detailed environmental study for the Erongo and Kunene coastlines, detailing nursery / spawning grounds and biodiversity. They also provided the draft report (not yet completed at the time of compiling this report) for the southern coastal areas (Karas and Hardap Regions).

Resource provided:

- NACOMA: *Strategic Environmental Assessment (SEA) for the coastal areas of the Erongo and Kunene Regions*, Study Report for Ministry of Environment and Tourism, January 2008
- NACOMA / DHI: *Strategic Environmental Assessment (SEA) for the coastal areas of the Karas and Hardap Regions (DRAFT)*, Study Report for Ministry of Environment and Tourism, April 2009
- Ministry of Fisheries and Marine Resources (Swakopmund, contacted telephonically and via email, physically visited prior to stakeholder interactions): The Ministry provided distributions of each group (bird species, invertebrate species, near-shore fish assemblages, plant species, location of seal colonies and location of right whale sightings, in MS Excel format).
- Ministry of Fisheries and Marine Resources (Lüderitz, contacted telephonically and via email): The relevant persons at the Ministry could not provide detailed information on Namibian Rock Lobsters.
- WWF South Africa (contacted via email): The WWF provided a detailed study of the islands off the coast of Namibia, detailing nursery / spawning grounds and biodiversity.

Resource provided:

- WWF South Africa: *Namibia Islands' Marine Protected Areas*, Report to Ministry of Environment and Tourism, 2008 (2008/Marine/003)
- Walvisbay Municipality provided a key biodiversity report for their local area.

Resource provided:

- The Local Action for Biodiversity (LAB) Project: *Biodiversity Report 2008*, Walvisbay Municipality, 2008

9. Annex II – Inundation mapping

9.1. Walvisbay



ASSUMPTIONS:

- On the main figure, it is assumed that LLD (Lowest Level Datum) is at the 0m contour
- Walvis Bay is assumed to be in the category of "inland environment" (refer to report)

OUTPUT:

- The present situation, 100 year storm level, is therefore expected to reach the 2009 LLD + 1m (specified as 1.5m but rounded down to 1m due to limited contour resolution) = 1m contour line
- The situation in 2100, is almost the same as for the present day. It is important to note that absolute storm probabilities increase due to global warming effects. These levels may be accepted as an annual basis.

Based on various stabilization levels of CO2:
(Year 2100 CO2 concentration at 500ppm)

Project:

UNFCCC Sea Level Change Impacts

Drawing title:
WALVIS BAY SEA LEVEL CHANGE IMPACTS

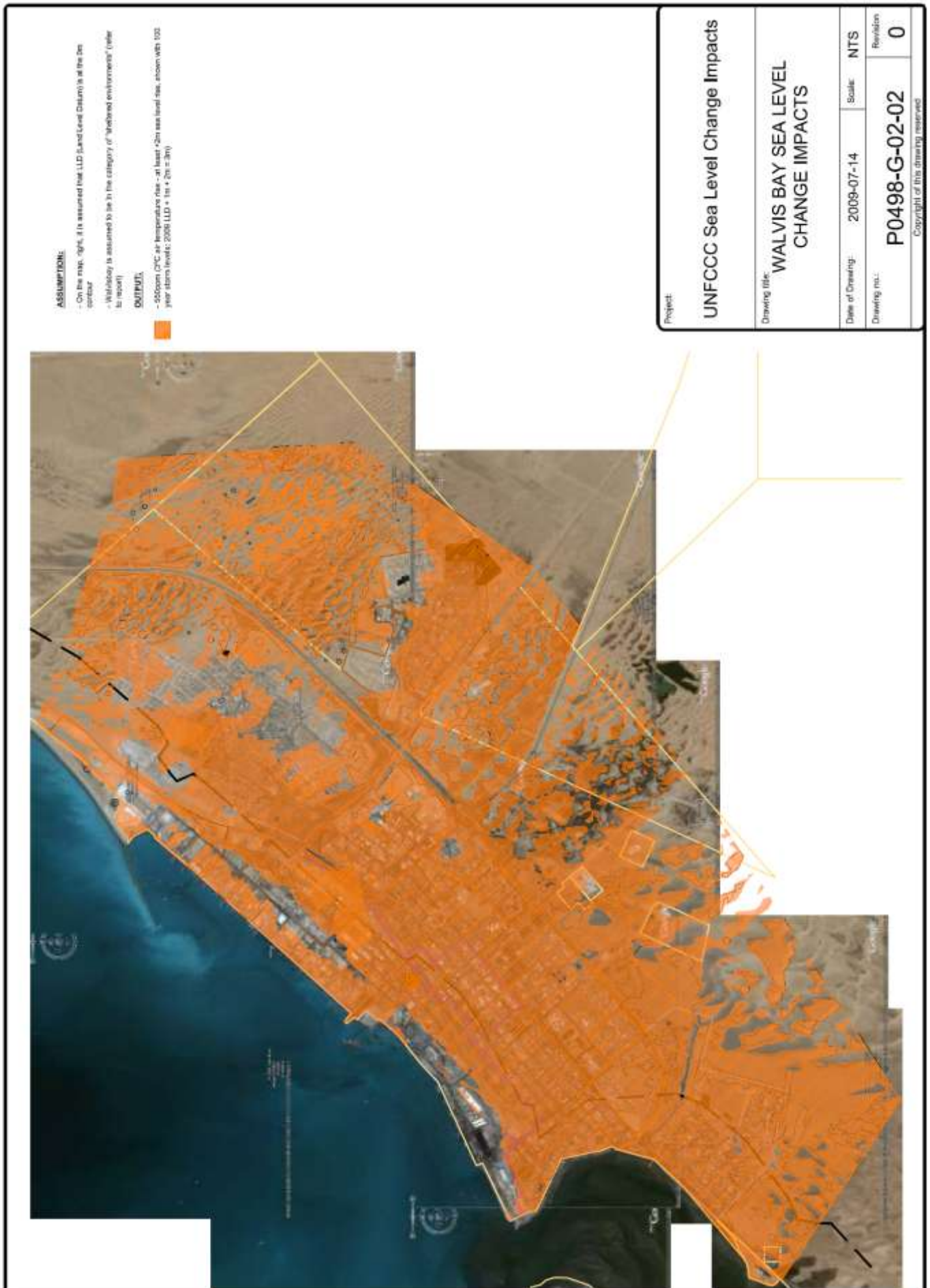
Date of Drawing:	2009-07-14	Scale:	NTS
Drawing no.:	P0498-G-02-02	Revision	0

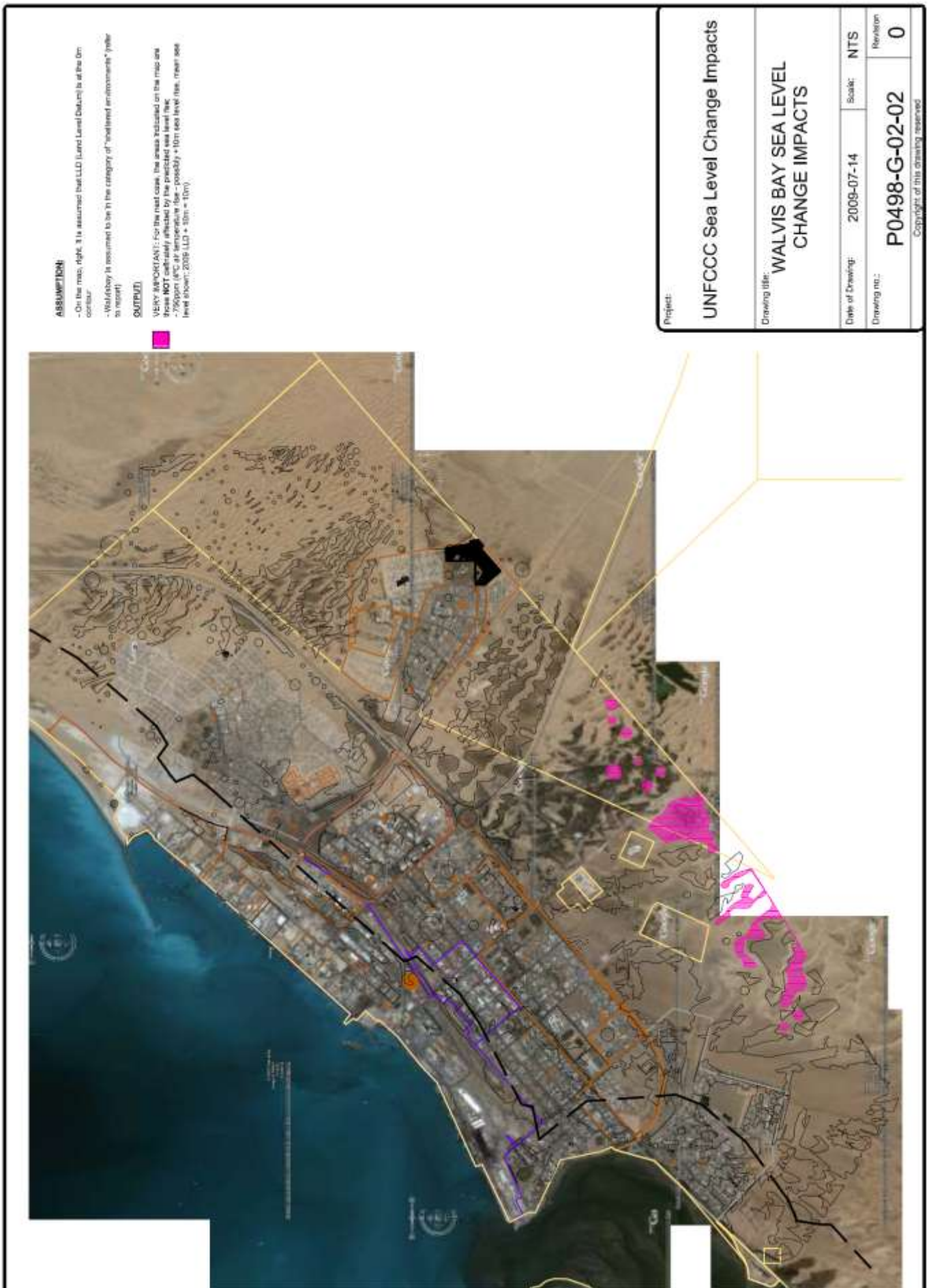
Copyright of this drawing reserved



Project: UNFCCC Sea Level Change Impacts			
Drawing title: WALVIS BAY SEA LEVEL CHANGE IMPACTS			
Date of Drawing:	2009-07-14	Scale:	N1S
Drawing no.:	P0498-G-02-02	Revision	0

Copyright of this drawing reserved





ASSUMPTION:

- On the map, right, it is assumed that LLD (Land Level Datum) is at the 0m contour
- Wetland is assumed to be in the category of "lowland environments" (refer to report)

OUTPUT:

VERY IMPORTANT: For the most cases, the areas indicated on the map are those NOT adversely affected by the predicted sea level rise.
 -750ppm (RCP air temperature rise - possibly +10m sea level rise, mean sea level shown; 2035 LLD + 50m = 10m)

Project:

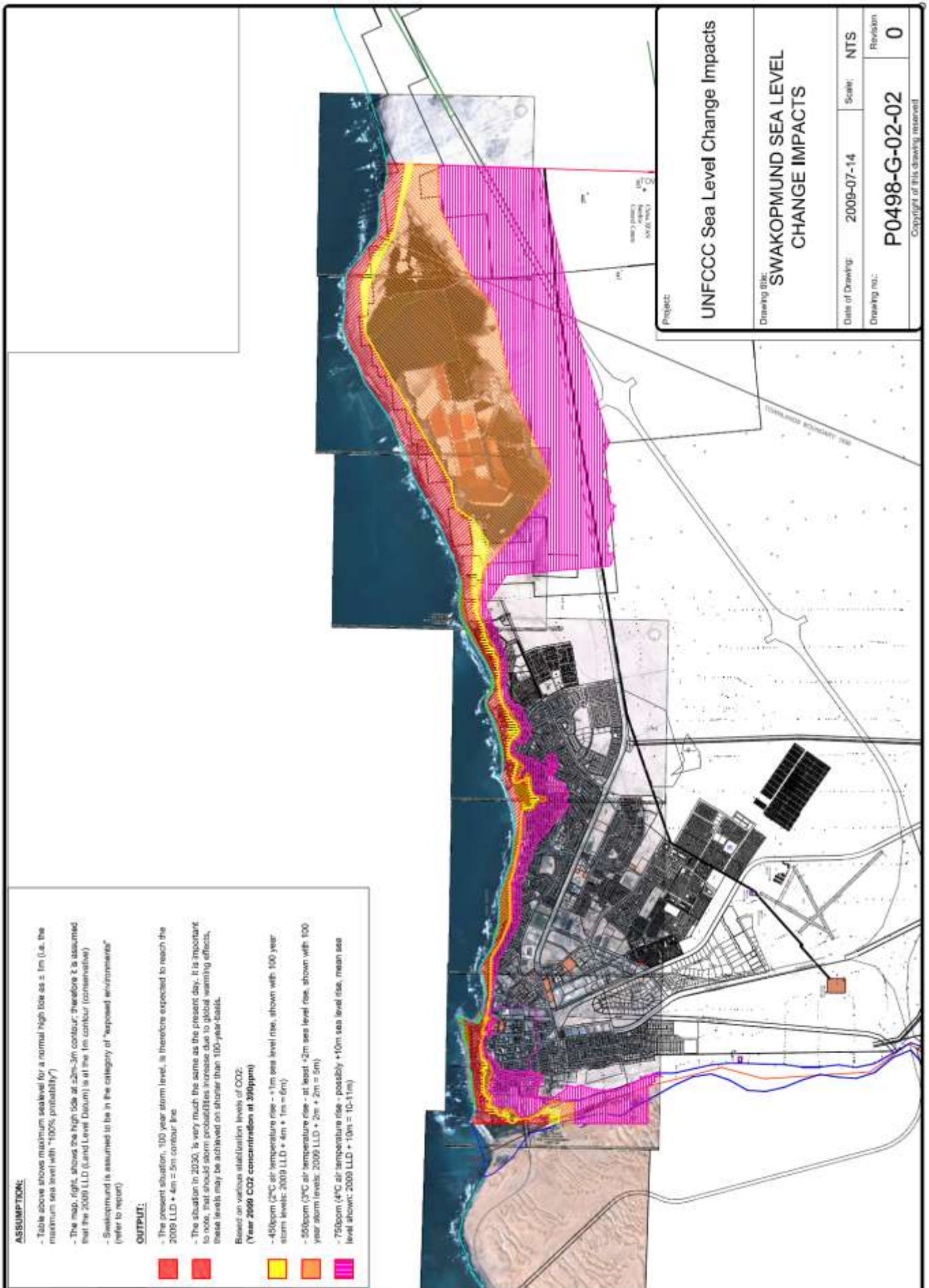
UNFCCC Sea Level Change Impacts

Drawing title:
WALVIS BAY SEA LEVEL CHANGE IMPACTS

Date of Drawing:	2009-07-14	Scale:	NTS
Drawing no.:	P0498-G-02-02		Revision
			0

Copyright of this drawing reserved

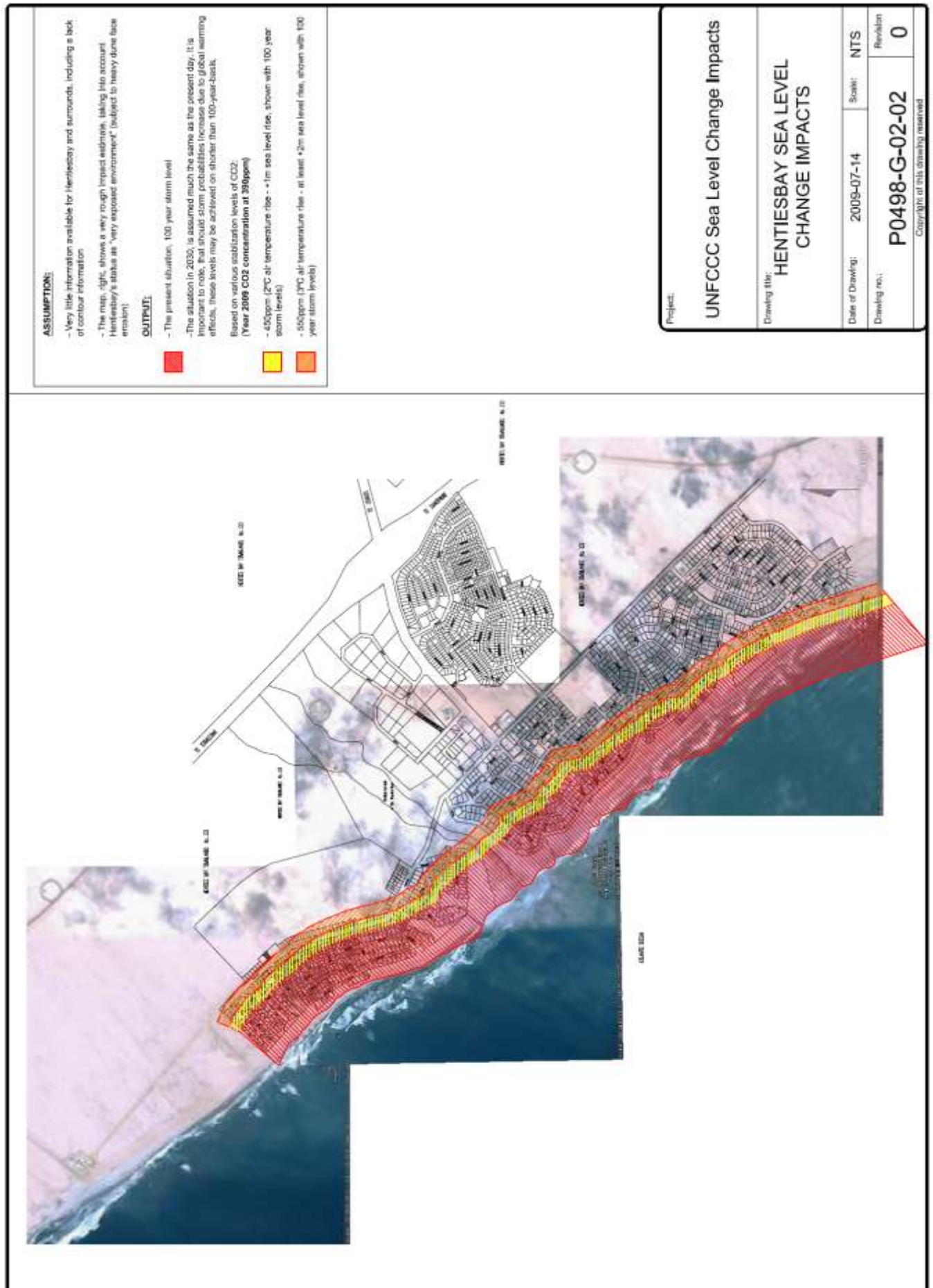
9.2. **Swakopmund**



9.3. Lüderitz

No detailed mapping could be obtained for Lüderitz. Please refer to interurban area mapping.

9.4. **Hentiesbay**



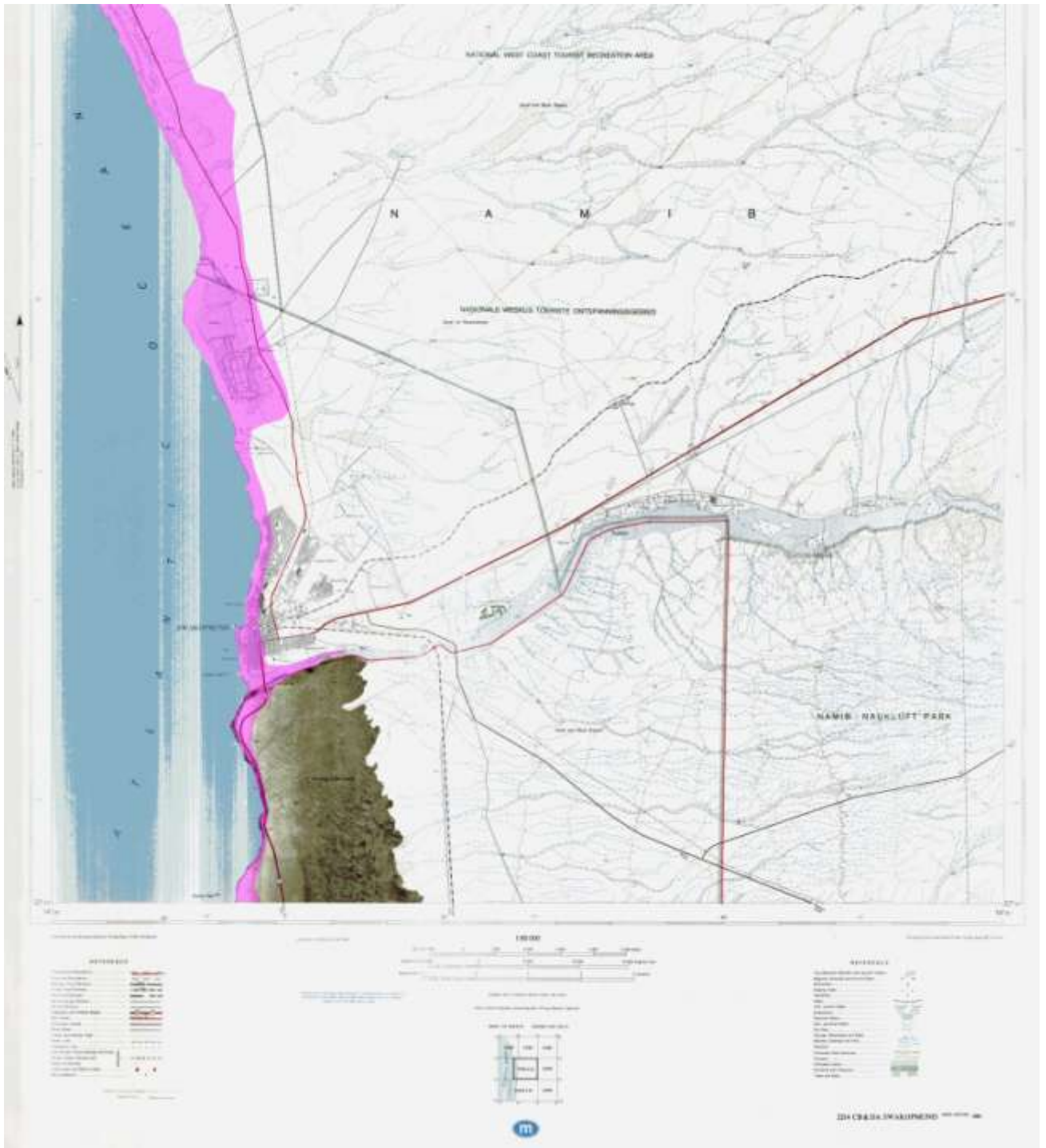
9.5. **Long Beach and Dolphin Beach**

No detailed mapping could be obtained for Lüderitz. Please refer to interurban area mapping.

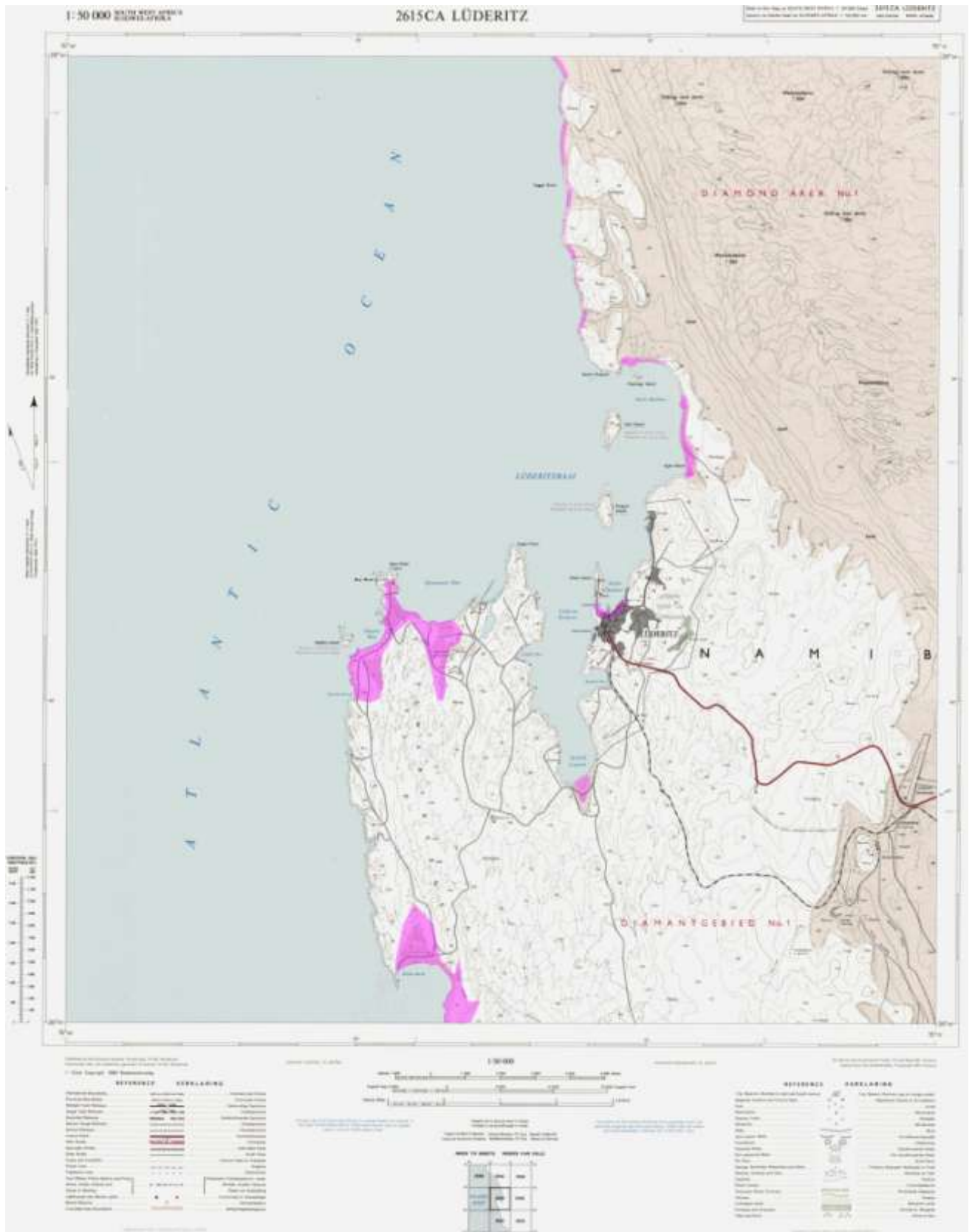
9.6. **Interurban areas**

The **maximum** extent of damage for all scenarios combined are shown (i.e. polar ice cap melt scenario).

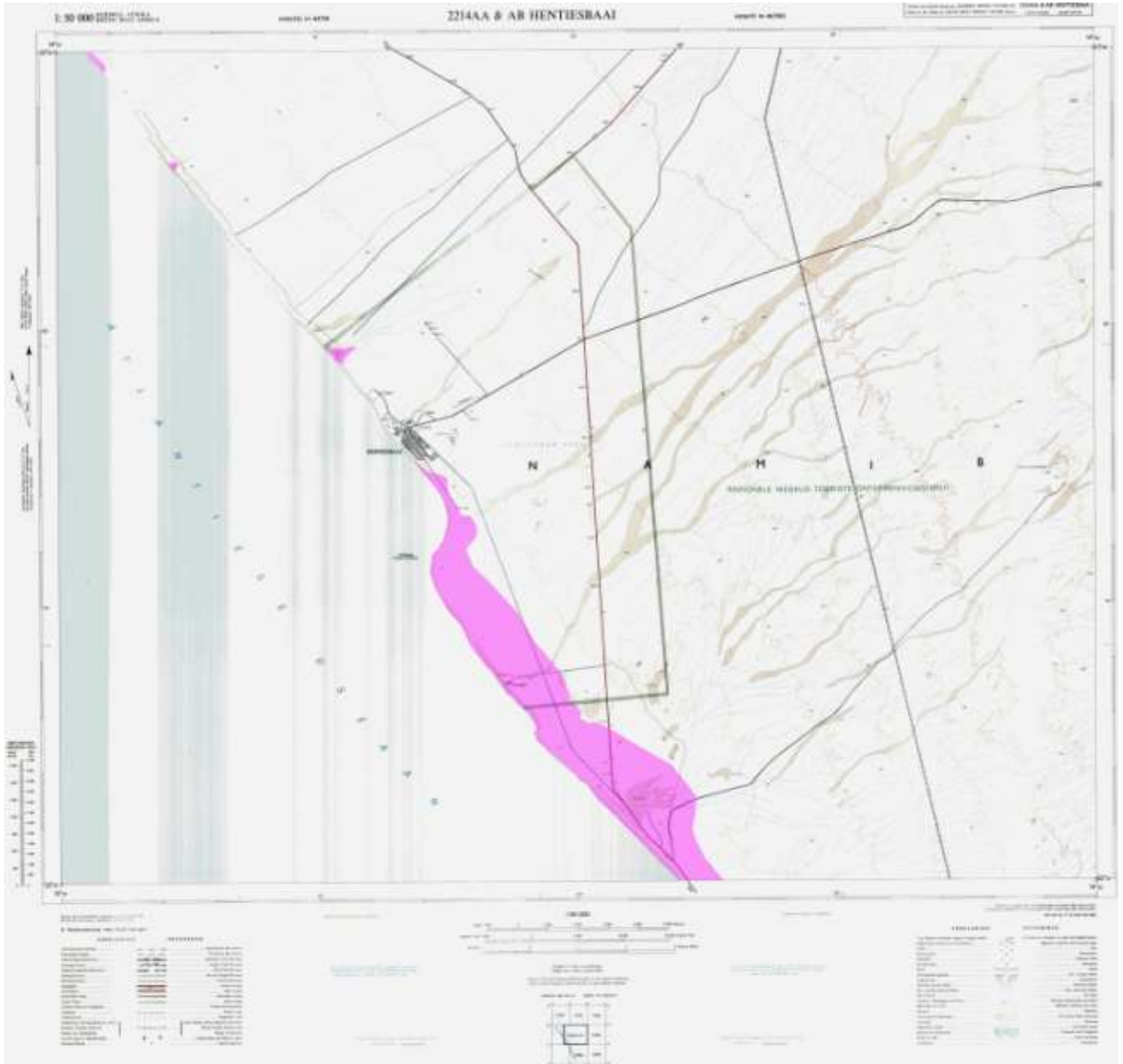
Walvisbay / Swakopmund



Lüderitz



Hentiesbay



10. Annex III – Calculations

1. Estimated economic activity

(Per capita GDP x human settlement populations)

1.1 Namibia's 2007 economic activity	:	(GDP per capita)	N\$ 47,400.00
1.2 Walvisbay (2007 est)	:	Population	42,015
		Activity (mil.N\$)	<u>N\$ 1,992</u>
1.3 Swakopmund (2007 est)	:	Population	28,554
		Activity (mil.N\$)	<u>N\$ 1,353</u>
1.4 Ludertiz (2007 est)	:	Population	12,139
		Activity (mil.N\$)	<u>N\$ 575</u>
1.5 Hentiesbay (2007 est)	:	Population	3,000
		Activity (mil.N\$)	<u>N\$ 142</u>
1.6 Long - & Dolphin beach (2007 est)	:	Population	500
		Activity (mil.N\$)	<u>N\$ 24</u>

2. Walvisbay

2.1 Projected development

- Financial, to 2009 (at 3.5% pa)	Activity (mil.N\$)	N\$	2,134
- Financial, to 2030 (at 3.5% pa)	Activity (mil.N\$)	N\$	4,395
- Currency value, to 2030 (10% inflation)			-86%
- Infrastructure at 2009 (number of erven)			10,914
- Infrastructure, to 2030 (number of erven; growth at 3% pa)			20,303

2.2 Property loss through sea level rise

No. of properties (2009)	Average stand rate N\$/m ² (2009)	Size (m ²)	Average building rate N\$/m ² (2009)	Size (m ²)	2009 Impact value
A	B	C	D	E	A*(B*C+D*E)
530	700	775	5,500.00	150	N\$ 724 mil 4.9%
No. of properties (2030)	2009 Rate		Average building rate N\$/m ² (2009)		2009 Impact value
985	668	775	5,500.00	150	N\$ 1,323 mil 4.9%
16,968	605	775	5,500.00	150	N\$ 21,951 mil 83.6%
19,636	597	775	5,500.00	150	N\$ 25,278 mil 96.7%
<i>Difference</i>					<i>N\$ 3,327 mil</i>
20,303	595	775	5,500.00	150	N\$ 26,106 mil 100.0%
<i>Difference</i>					<i>N\$ 828 mil</i>

2.3 Road & storm water infrastructure damage / loss through sea level rise

Road type (2009)	Road rate N\$/km (2009)	Length (km)	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1. Salt	550,000	8	1.00		N\$ 4.40 mil
Bitumen	950,000	39	0.75		N\$ 27.61 mil
2030 Scenarios	2009 Rate				2009 Impact value
2. Salt	550,000	24.2	1.00		N\$ 13.30 mil
Bitumen	950,000	62.8	0.75		N\$ 44.73 mil
3(a) Salt	550,000	87.1	1.00		N\$ 47.88 mil
Bitumen	950,000	226.0	1.00		N\$ 214.72 mil
3(b) Salt	550,000	90.0	1.00		N\$ 49.48 mil
Bitumen	950,000	233.6	1.00		N\$ 221.88 mil
3(c) Salt	550,000	96.7	1.00		N\$ 53.20 mil
Bitumen	950,000	251.1	1.00		N\$ 238.58 mil

The road rate is defined as only the capital costs for instating/reinstating roads
Extent of damage factor based on extent of sea ingress and vulnerability

2.3 Sewer & water infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	13,300	530	0.25		N\$ 1.76 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	13,300	985	0.25		N\$ 3.3 mil
3(a)	13,300	16968	0.90		N\$ 203 mil
3(b) Total	13,300	19636	1.00		N\$ 261 mil
<i>Difference</i>					N\$ 58 mil
3(c) Total	13,300	20303	1.00		N\$ 270 mil
<i>Difference</i>					N\$ 8.87 mil

Extent of damage factor based on extent of sea ingress and vulnerability

2.4 Electricity infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	
1	16,520	530	0.25		N\$ 2.2 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	16,520	985	0.25		N\$ 4 mil
3(a)	16,520	16968	0.90		N\$ 252 mil
3(b) Total	16,520	19636	1.00		N\$ 324 mil
<i>Difference</i>					N\$ 72 mil
3(c) Total	16,520	20303	1.00		N\$ 335 mil
<i>Difference</i>					N\$ 11.02 mil

Extent of damage factor based on extent of sea ingress and vulnerability

3. Swakopmund

3.1 Projected development

- Financial, to 2009 (at 3.5% pa) **Activity (mil.N\$)**
- Financial, to 2030 (at 3.5% pa) **Activity (mil.N\$)**
- Currency value, to 2030 (10% inflation)
- Infrastructure at 2009 (number of erven)
- Infrastructure, to 2030 (number of erven; growth at 3% pa)

3.2 Property loss through sea level rise

No. of properties (2009)	Average stand rate N\$/m ² (2009)	Size (m ²)	Average building rate N\$/m ² (2009)	Size (m ²)	2009 Impact value
A	B	C	D	E	A*(B*C+D*E)
260	900	950	6,000.00	200	N\$ 534 mil
No. of properties (2030)	2009 Rate		Average building rate N\$/m ² (2009)		2009 Impact value
320	883	950	6,000.00	200	N\$ 652 mil
400	865	900	6,000.00	200	N\$ 792 mil
500	848	850	6,000.00	200	N\$ 960 mil
<i>Difference</i>					<i>N\$ 169 mil</i>
1500	792	850	6,000.00	200	N\$ 2,809 mil
<i>Difference</i>					<i>N\$ 1,849 mil</i>

3.3 Road & storm water infrastructure damage / loss through sea level rise

Road type (2009)	Road rate N\$/km (2009)	Length (km)	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1. Salt	550,000	1.43	1.00		N\$ 0.79 mil
Bitumen	950,000	1.33	0.75		N\$ 0.95 mil
2030 Scenarios	2009 Rate				2009 Impact value
2. Salt	550,000	1.63	1.00		N\$ 0.90 mil
Bitumen	950,000	1.71	0.75		N\$ 1.22 mil
3(a) Salt	550,000	2.05	1.00		N\$ 1.13 mil
Bitumen	950,000	1.9	1.00		N\$ 1.81 mil
3(b) Salt	550,000	2.3	1.00		N\$ 1.27 mil
Bitumen	950,000	2.25	1.00		N\$ 2.14 mil
3(c) Salt	550,000	2.8	1.00		N\$ 1.54 mil
Bitumen	950,000	6.2	1.00		N\$ 5.89 mil

The road rate is defined as only the capital costs for instating/reinstating roads
Extent of damage factor based on extent of sea ingress and vulnerability

3.3 Sewer & water infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	13,300	260	0.10		N\$ 0.35 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	13,300	320	0.10		N\$ 0.4 mil
3(a)	13,300	400	1.00		N\$ 5.3 mil
3(b) Total	13,300	500	1.00		N\$ 6.7 mil
<i>Difference</i>					N\$ 1.3 mil
3(c) Total	13,300	1500	1.00		N\$ 19.95 mil
<i>Difference</i>					N\$ 13.30 mil

Extent of damage factor based on extent of sea ingress and vulnerability

3.4 Electricity infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	16,520	260	0.25		N\$ 1.07 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	16,520	320	0.25		N\$ 1 mil
3(a)	16,520	400	1.00		N\$ 7 mil
3(b) Total	16,520	500	1.00		N\$ 8 mil
<i>Difference</i>					N\$ 2 mil
3(c) Total	16,520	1500	1.00		N\$ 24.78 mil
<i>Difference</i>					N\$ 16.52 mil

Extent of damage factor based on extent of sea ingress and vulnerability

4. Luderitz

4.1 Projected development

- Financial, to 2009 (at 3.5% pa)	Activity (mil.N\$)	N\$ 616
- Financial, to 2030 (at 3.5% pa)	Activity (mil.N\$)	N\$ 1,269
- Currency value, to 2030 (10% inflation)		-86%
- Infrastructure at 2009 (number of erven)		3,598
- Infrastructure, to 2030 (number of erven; growth at 3% pa)		6,693

4.2 Property loss through sea level rise

No. of properties (2009)	Average stand rate N\$/m ² (2009)	Size (m ²)	Average building rate N\$/m ² (2009)	Size (m ²)	2009 Impact value
A	B	C	D	E	A*(B*C+D*E)
80	700	805	6,000.00	150	N\$ 117 mil 2.2%
No. of properties (2030)	2009 Rate		Average building rate N\$/m ² (2009)		2009 Impact value
149	668	805	6,000.00	150	N\$ 214 mil 2.2%
164	662	805	6,000.00	150	N\$ 235 mil 2.4%
196	651	805	6,000.00	150	N\$ 280 mil 2.9%
<i>Difference</i>					<i>N\$ 45 mil</i>
295	629	805	6,000.00	150	N\$ 414 mil 4.4%
<i>Difference</i>					<i>N\$ 135 mil</i>

4.3 Road & storm water infrastructure damage / loss through sea level rise

Road type (2009)	Road rate N\$/km (2009)	Length (km)	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1. Salt	550,000	0			N\$ - mil
Bitumen	950,000	0			N\$ - mil
2030 Scenarios	2009 Rate				2009 Impact value
2. Salt	550,000	0			N\$ - mil
Bitumen	950,000	0			N\$ - mil
3(a) Salt	550,000	0			N\$ - mil
Bitumen	950,000	9.3	1.00		N\$ 8.84 mil
3(b) Salt	550,000	0			N\$ - mil
Bitumen	950,000	11.2	1.00		N\$ 10.60 mil
3(c) Salt	550,000	0			N\$ - mil
Bitumen	950,000	13.0	1.00		N\$ 12.37 mil

The road rate is defined as only the capital costs for instating/reinstating roads
Extent of damage factor based on extent of sea ingress and vulnerability

4.3 Sewer & water infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	15,300	80	0.10		N\$ 0.12 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	15,300	149	0.10		N\$ 0.2 mil
3(a)	15,300	164	1.00		N\$ 2.5 mil
3(b) Total	15,300	196	1.00		N\$ 3.0 mil
<i>Difference</i>					N\$ 0.5 mil
3(c) Total	15,300	295	1.00		N\$ 4.51 mil
<i>Difference</i>					N\$ 1.50 mil

Extent of damage factor based on extent of sea ingress and vulnerability

4.4 Electricity infrastructure damage / loss through sea level rise

2009 Scenarios	Replacement rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	16,520	80	0.25		N\$ 0.33 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	16,520	149	0.25		N\$ 0.6 mil
3(a)	16,520	164	1.00		N\$ 2.7 mil
3(b) Total	16,520	196	1.00		N\$ 3.2 mil
<i>Difference</i>					N\$ 0.5 mil
3(c) Total	16,520	295	1.00		N\$ 4.87 mil
<i>Difference</i>					N\$ 1.62 mil

Extent of damage factor based on extent of sea ingress and vulnerability

5. Hentiesbay

5.1 Projected development

- Financial, to 2009 (at 3.5% pa)	Activity (mil.N\$)	N\$ 152
- Financial, to 2030 (at 3.5% pa)	Activity (mil.N\$)	N\$ 313
- Currency value, to 2030 (10% inflation)		-86%
- Infrastructure at 2009 (number of erven)		2,633
- Infrastructure, to 2030 (number of erven; growth at 3% pa)		4,898

5.2 Property loss through sea level rise

No. of properties (2009)	Average stand rate N\$/m ² (2009)	Size (m ²)	Average building rate N\$/m ² (2009)	Size (m ²)	2009 Impact value
A	B	C	D	E	A*(B*C+D*E)
55	800	805	6,000.00	150	N\$ 85 mil 2.1%
No. of properties (2030)	2009 Rate		Average building rate N\$/m ² (2009)		2009 Impact value
102	763	805	6,000.00	150	N\$ 155 mil 2.1%
113	756	805	6,000.00	150	N\$ 170 mil 2.3%
197	724	805	6,000.00	150	N\$ 292 mil 4.0%
<i>Difference</i>					<i>N\$ 122 mil</i>
295	700	805	6,000.00	150	N\$ 432 mil 6.0%
<i>Difference</i>					<i>N\$ 140 mil</i>

5.3 Road & storm water infrastructure damage / loss through sea level rise

Road type (2009)	Road rate N\$/km (2009)	Length (km)	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1. Salt	550,000	0			N\$ - mil
Bitumen	950,000	0			N\$ - mil
2030 Scenarios	2009 Rate				2009 Impact value
2. Salt	550,000	0			N\$ - mil
Bitumen	950,000	0			N\$ - mil
3(a) Salt	550,000	4.5	1.00		N\$ 2.48 mil
Bitumen	950,000	0			N\$ - mil
3(b) Salt	550,000	5.04	1.00		N\$ 2.77 mil
Bitumen	950,000	0			N\$ - mil
3(c) Salt	550,000	7.29	1.00		N\$ 4.01 mil
Bitumen	950,000	0			N\$ - mil

The road rate is defined as only the capital costs for instating/reinstating roads
Extent of damage factor based on extent of sea ingress and vulnerability

5.3 Sewer & water infrastructure damage / loss through sea level rise

2009 Scenarios	Replace ment rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	15,300	55	0.10		N\$ 0.08 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	15,300	102	0.10		N\$ 0.2 mil
3(a)	15,300	113	1.00		N\$ 1.7 mil
3(b) Total	15,300	197	1.00		N\$ 3.0 mil
<i>Difference</i>					N\$ 1.3 mil
3(c) Total	15,300	295	1.00		N\$ 4.52 mil
<i>Difference</i>					N\$ 1.51 mil

Extent of damage factor based on extent of sea ingress and vulnerability

5.4 Electricity infrastructure damage / loss through sea level rise

2009 Scenarios	Replace ment rate N\$/erf (2009)	No. of stands	Extent of damage factor		2009 Impact value
A	B	C	D	E	B*C*D
1	16,520	55	0.25		N\$ 0.23 mil
2030 Scenarios	2009 Rate				2009 Impact value
2	16,520	102	0.25		N\$ 0.4 mil
3(a)	16,520	113	1.00		N\$ 1.9 mil
3(b) Total	16,520	197	1.00		N\$ 3.3 mil
<i>Difference</i>					N\$ 1.4 mil
3(c) Total	16,520	295	1.00		N\$ 4.88 mil
<i>Difference</i>					N\$ 1.63 mil

Extent of damage factor based on extent of sea ingress and vulnerability

11. Annex IV – Stakeholder workshop, 24 July 2009

11.1. List of invitees

List of Persons to Invite to Workshop

Sea Level Rise: Impacts and Adaptation Strategy

#	NAME	POSITION	INSTITUTION	CONTACT DETAILS	Remarks
1.	Mr. Pierre du Plessis	NCCC	CRIAA/SA-DC	Pierre@criaasadc.org Tel: 254766; Fax: Cell: 081-251 0672	
2.	Dr. Moses Maurihungirire	Deputy Director: Resource Management – NCCC	Ministry of Fisheries and Marine Resources – Resource Management	mmaurihungirire@mfmr.gov.na Tel: 205 3071; Fax: 220558 Cell: 081-129 3145 Private Bag 13355, Windhoek	
3.	Mr. Sem Shikongo	Director of Tourism NCCC	Ministry of Environment and Tourism	sts@dea.met.gov.na Tel: 249015; Fax: 240339	
4.	Mr. Immanuel Nghishoonge	Chief Economist – NCCC	Ministry of Mines and Energy	inghishoonge@mme.gov.na Private Bag 13297, Windhoek Tel: 284 8224; Fax: 238 643	
5.	Mr. Franz /Uirab	Deputy Director: National Met. Services – NCCC	MWTC – Namibia Meteorological Services	fuirab@meteona.com	
6.	Mr. Sepiso Mwangala	NCCC	MWTC- Climate & Data Bank, National Meteorological Services	smwangala@yahoo.co.uk Tel: 287 7012; Fax: 287-7009	
7.	Mr. I J (Sakkie) Coetzee (The alternate is also Elaine Smith)	Executive Manager – NCCC	Namibia Agricultural Union (NAU)	sakkie@agrinamibia.com.na Private Bag 13255, Windhoek Tel:237838/9; Fax: 220193	
8.	Mr. Nico P. du Plessis	Senior Environmentalist – NCCC	Namibia Water Corporation (Namwater)	PlessisN@namwater.com.na Tel: 712093; Fax: 713093 Cell: 081-127 9040	

#	NAME	POSITION	INSTITUTION	CONTACT DETAILS	Remarks
				Private Bag 13389, Windhoek	
9.	Mr. John Langford (Ms. Gloudina de Beer as alternate)	General Manager; Strategic Planning – NCCC	Nampower	Gloudina.debeer@nampower.com.na John.Langford@nampower.com.na P.O. Box 2864, Windhoek Tel:205-2202, 4111; Fax: 205-2368 Cell: 081-124 7409	
10.	Ms. Marina E Coetzee	Chief Researcher, AEZ Programme NCCC	Ministry of Agriculture, Water and Forestry	mec@iway.na Tel:2087070	marina.e.coetzee@gmail.com
11.	Ms. Maxi Louis	Coordinator	Namibia Association for CBNRM Support Organisations (NACSO)	maxi@nacso.org.na Tel: 230888 Fax: 230863	
12.	Ms. Martha Mwandingi	Head: Environment Unit	UNDP Namibia	Martha.mwandingi@undp.org	
13.	Dr. Joh Henschel	Director	Gobabeb Training & Research Institute (GTRC) (MET/DRFN)	C/o DRFN Fax: 064: 694 197 Tel: 064 694 199, Tel: 061-229855	
14.	Mr. Shimweefeleni Hamutwe	Energy Technical Advisor	Ministry of Mines and Energy	ghamutwe@mme.gov.na Private Bag 13297, Windhoek Tel: 284-8111; Fax: 284-8200	
15.	Ms. Saara Hamunyela (with Ms. Petrina Nakale the D.Director)		Ministry of Trade and Industry: The National Ozone office	Tel: 283 7111; Fax 221 729 hamuneyla@mti.gov.na	
16.	Ms. Angeline Simana	Director: Transport Policy	Ministry of Works Transport and Communication	asimana@mwtc.gov.na Tel: 208-8827 (702213); Fax: 208-8890 Private Bag 13341, Windhoek	
17.	Dr. Chris Brown	Executive Director	Namibia Nature Foundation	chrisbrown@nnf.org.na Tel: 248345; Fax: 248344 P.O. Box 245, Windhoek	
18.	Mr. Sylvester Kamwi	Development Planner	National Planning Commission	kamwi@hotmail.com Tel: 061 – 283 4121; Fax:061- 22 65 01	

#	NAME	POSITION	INSTITUTION	CONTACT DETAILS	Remarks
19.	Mr. Andreas Wienecke	Manager: Research	Habitat Research & Development Centre	andreas_hrdc@yahoo.com Tel: 268211; Fax: 268201 Cell: 081-128 8102	
20.	Mr. Dave Sampson		Ministry of Basic Education and culture (MBESC): NIED	dsampson@nied.edu.na Tel: 062-50 2446; Fax: 062-502 613	
21.	Dr. Gillian L Maggs-Kolling	Head of Institute: NBRI	National Botanical Research Institute	gmk@mweb.com.na Tel: 202 2020; Fax: 258153 Private Bag 13184 Windhoek	
22.	Mr. Ibo Zimmerman		Polytechnic of Namibia	ibozim@polytechnic.edu.na P/Bag13388, Windhoek Tel: 2072461; Fax :2072143	
23.	Mr. Kudakwashe Ndhlukula	Coordinator	Renewable Energy And Energy Efficiency Institute	kndhlukula@polytechnic.edu.na	
24.	Dr. Mary Seely	Member	Desert Research Foundation of Namibia	mary.seely@drfn.org.na	
25.	Ms. Bertchen Kohrs	Coordinator	EarthLife Namibia	Tel: 227913 earthl@iway.na	
26.	Mr. Rod Braby	Senior Technical Advisor	Namibia Coast Conservation and Management Project (NACOMA)	rbraby@nacoma.org.na	
27.	Mr. Manuel Mbuende		MAWF	mbuendemr@hotmail.com	
28.	Mr. Detlof von Oertzen	Director	VO Consulting	voconsulting@mweb.com.na	
29.	Mr. Andre Brummer	General Manager: Water, Waste and Environmental Management	Municipality of Walvis Bay	abrummer@walvisbaycc.org.na Tel: (064) 214305	
30.	Mr Clive Lawrence	General Manager: Health	Municipality of Swakopmund	clawrence@swkmun.com.na 064-4104325	
31.	Mr Niclas De Wee	Health Inspector	Municipality of Luderitz	nico@lrc.com.na 063 – 202041 or 0812849209	
32.	Mr P. L. Gurirab	Chief Executive Officer	Municipality of Henties Bay	To be faxed to (064) 502001 for att. Mr Jeremiah Khaiseb but addressed to	

#	NAME	POSITION	INSTITUTION	CONTACT DETAILS	Remarks
				CEO	
33.	Mr Tony Raw and Tim Aiman	Port Engineer Coordinator for EMS	NamPort: Port of Walvis Bay	tony@namport.com.na and tim@namport.com.na Tel: 064 - 2082111	
34.	Mr. Ted Rudd	Planner	Urban Dynamics	ted@uda.com.na 061 - 2403000	
35.	Mr. Jerry Stubenrauch	Planner	Stubenrauch Planning Consultants	gunther@spc.iway.na 061 - 251189	
36.	Ms. Stephanie Van Zyl	Environmental Manager	Enviro dynamics	Stephanie@envirod.com 061- 223336	
37.	Mr. John Pallet	Environmental Manager	SAEIA	John.pallet@saiea.com 061 - 259183	
38.	Mr Klein Snr	Director	Salt Company	saltco@africaonline.com.na 064 - 402611	
39.	Mr Roy Stanton	Director	Salt and Chemicals	Roy@wbsalt.com 064 - 202304	
40.	Mr Hendrik Van Der Westhuizen	Managing Director	Hangana Seafood (PTY) LTD	Hendrik.vander@olfitra.com.na 064 - 218400	
41.	Mr Antonio Marino	Managing Director	Tunacor Fisheries LTD	Antonio@tunacor.com.na 064 - 218100	
42.	Mr S.T. Kathindi	Managing Director	Etale Fishing Company (PTY) LTD	bobboh@etalefishing.com 064 - 218700	
43.	Mr P.J. Conradie	Manager Director	Etosha Fishing Corporation (PTY) LTD	mvanwyk@etoshafish.com 064 - 215600	
44.	Ms Anja van der Plas	Marine Biologist	MFMR	Avanderplas@mfmr.gov.na	
45.	Mr Chris Bartholomew	Marine Biologist	MFMR	C.Bartholomew@mfmr.gov.na	
46.	Mr Gondi Diaz	Resource Economist	MFMR	gdiroz@mfmr.gov.na	
47.	Ms Hersig	Tour Consultant	Sunrise Tours and Safaris	sunrisetours@iafrica.com.na 064 - 404561	
48.	Ms Cathy Visser		Levo Chalets and Dolphin Tours	cathy@levotours.com 064 - 207555	

#	NAME	POSITION	INSTITUTION	CONTACT DETAILS	Remarks
49.	Ms Megan Dreyer	Director	Mola Mola Safaris	info@mola-namibia.com 064 - 205511	

11.2. Attendance register

SEA LEVEL RISE PROJECT WORKSHOP, ATLANTIC HOTEL, WALVIS BAY, 24 JULY 2009 MINISTRY OF ENVIRONMENT AND TOURISM

Organization	Name	Telephone	Email
Walvis Bay Municipality	Andre Brummer	064 214 301	abrummer@walvisbaycc.org.na
GCS Namibia	Mark Stanton	081 373 6854	marks@gcs-na.biz
Namibia Nature Foundation	John Paterson	064 204 044	john@albatross.org.na
Walvis Bay Municipality	Martin Amedick	064 214 309	mamedick@walvisbay.org.na
Walvis Bay Municipality	Beverly Fernandez	064 201 3357	bfernandez@walvisbay.org.na
Walvis Bay Municipality	Otaniel Kakero	064 201 2013348	okakero@walvisbay.org.na
Swakopmund Municipality	Clive Lawrence	064 403 412	clawrence@swkmun.com.na
Swakopmund Municipality	B. Portgieter	064 410 4240	bportgieter@swkmun.com.na
Ministry of Fisheries	M. Maurihungirire	061 205 3114	mmaurihungirire@mfmr.gov.na
Ministry of Fisheries	Asser Katunahange	081 221 8009	akatunahange@mfmr.gov.na
Ministry of Fisheries	Deon C. Louw	081 272 6116	dclouw@mfmr.gov.na
Henties Bay Municipality	J. Khaiseb	064 502 000	hbaytc@iway.na
Lithon Project Consultants	Danie Nel	061 250 278	danie@lithon.com
VO Consulting	Detlof von Oertzen	064 402 966	voconsulting@mweb.com.na
Ministry of Environment and Tourism	Uazamo Kaura	081 284 8280	uazamo@dea.met.gov.na
Ministry of Environment and Tourism	Jonas Nghishidi	061 284 2701	nghishidi@yahoo.co.uk
UNDP	Raul Alfaro	081 412 5579	raul.alfaro@undp.org
Coastal Environmental Trust of Namibia	Susan Roux	081 129 4935	cetn@iafrica.com.na
Hansawa	P.N. Auene	081 124 5163	Pinehaf.auene@iafrica.com.na
NamWater	NP du Plessis	081 127 9040	Plessisn@namwater.com.na
Sunrise Tours	Silke Bittle	064 2013348	sunrisetours@iafrica.com.na
Walvis Bay Slat Refinery	V. Tnzoo	064 213 350	Vazembua.muharukua@wbsalk.com
Ministry of Trade and Industry	M. Jjaimi	064 463 864	tjjaimi4@yahoo.co.uk
LaquaR Consultants	Lucinda Fairhurst	+27 21 510 6160	lucinda.fairhurst@gmail.com
Consulting Services Africa	Carter Hartz	061 237 427	carterh@csa-nam.com

11.3. Presentations

**A SEA LEVEL RISE ASSESSMENT
FOR THE COAST OF NAMIBIA**

Lucinda Fairhurst



lucindafairhurst@gmail.com

P.O. Box 474,
Eppindust,
Cape Town,
7475,
RSA

Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human pressure on coastal areas.
IPCC Fourth Assessment Report Feb 2007

The scientific evidence is now overwhelming: climate change presents very serious risks, and it demands an urgent global response.
Stern Review 2007

THE APPROACH

- Background to the model
- First Study
 - Present Day Very Worst Case Scenario
- Second Study
 - Scenario at the year 2030
- Third Study
 - Polar Ice Sheet Melt Scenario on century time scales
- Fourth Study
 - Vulnerable locations – Walvis Bay

Present Day Very Worst Case Scenario

Factors :

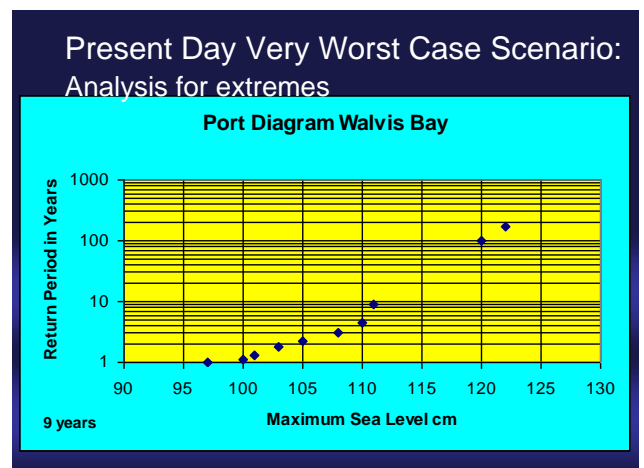
- Tides
- Weather
- Wave setup

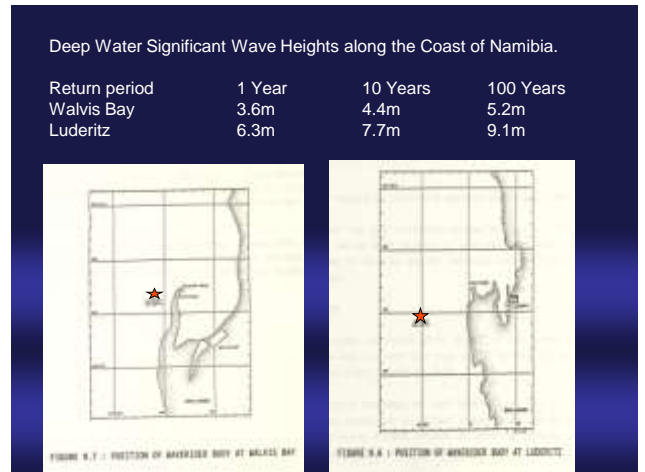
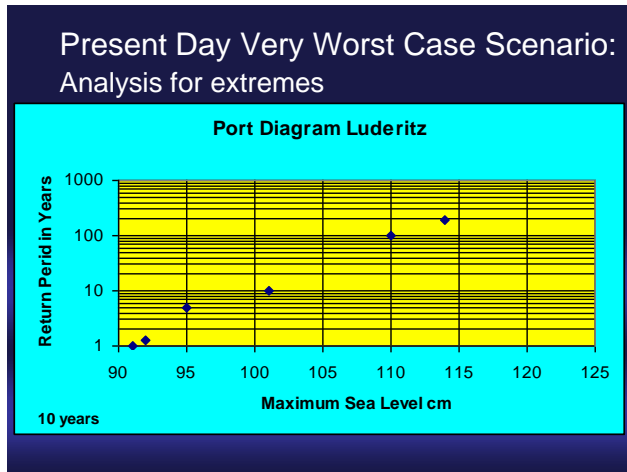
Present Day Very Worst Case Scenario

LLD = derived from the geodetic network used for land in Namibia.

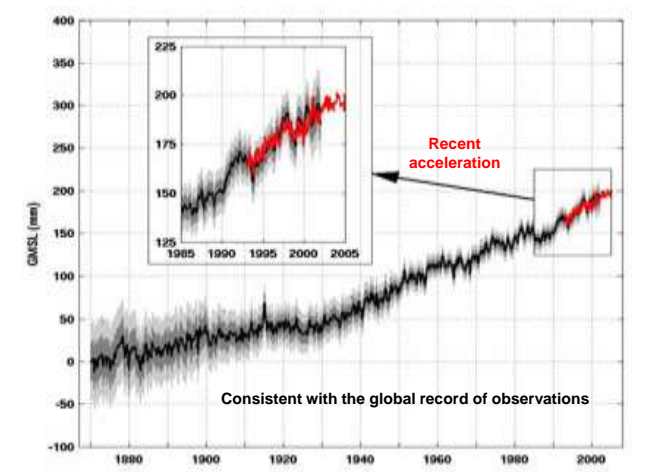
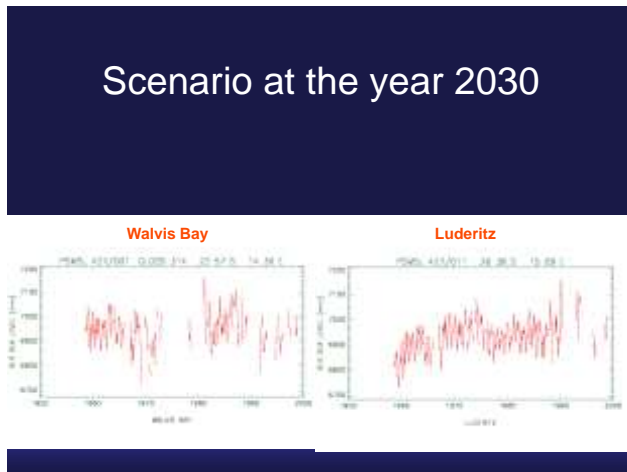
• TIDES	Walvis Bay	Luderitz
• Mean Tide Level	LLD	LLD-13cm
• Mean High Water Neaps	LLD+31cm	LLD+16cm
• Mean High Water Springs	LLD+71cm	LLD+54cm
• Highest Astronomical Tide	LLD+102cm	LLD+89cm

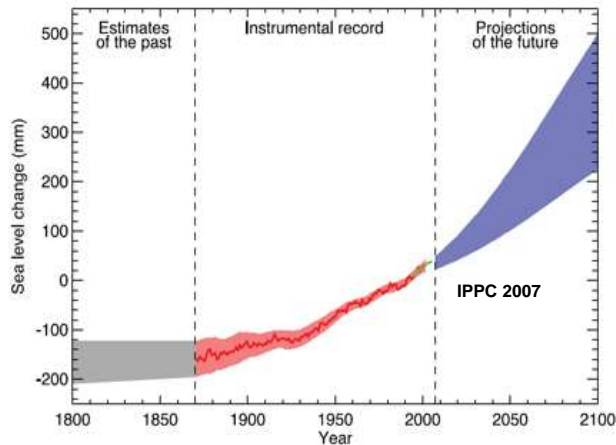
(HAT) = 18.6 year cycle
(HATOY) = will occur in spring or Autumn = 12 cm →2012





- ### Present Day Worst Case Scenario Southern Namibia
- Expected Maximum Sea Level
- Sheltered Coast LLD+1.5m
 - Exposed Coast LLD+4m
 - Very Exposed Coast LLD+6m
plus 30m of coastal erosion

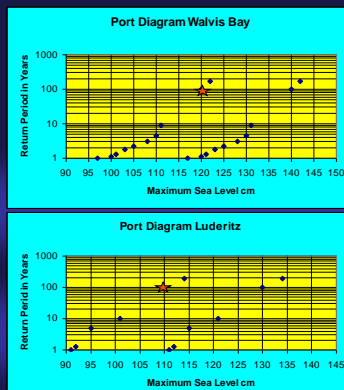




Accumulated sea level rise to 2030

Decade	revert	steady	accelerate
1980-1989	1.8cm	1.8cm	1.8cm
1990-1999	3.1cm	3.1cm	3.1cm
2000-2009	1.8cm	3.1cm	4.4cm
2010-2019	1.8cm	3.1cm	5.7cm
2020-2030	1.8cm	3.1cm	7.0cm
accumulated	10.3cm	14.2cm	22.0cm

Extreme Sea Levels Now and in 2030



Sea Level Scenario in 2030 Southern Namibia

Maximum Sea Levels

- Sheltered Coast LLD+1.5m
Expected **EVERY YEAR**
- Exposed Coast LLD+4m
- Very Exposed Coast LLD+6m
plus 30m of coastal erosion
Expected in worst case storms

Key Message 1: Climatic Trends Copenhagen March 2009

- Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realised.
- For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, **sea-level rise**, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events.
- There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.

Polar Ice Melt Scenario

- Ice Melt available for Sea Level Rise
- Temperate/tropical glaciers 0.5 m
- Greenland Ice Sheet 7 m
- West Antarctic Ice Sheet 5 m
- East Antarctic Ice Sheet 55 m
- Non-linear acceleration of polar ice melt
- No time scales available

European Response to 5m Sea Level Rise

- Rhone: Abandon to wetland
- Thames: London as Venice
- Rhine: Retreat from Western Netherlands

All Docklands Relocated

Catastrophic for Namibia

Sea Level Rise Impacts

World Bank study on Impacts of Sea Level Rise on Developing Countries 2007

Namibia is ranked 26 out of 29 countries in sub-Saharan Africa on most impact classes. The exceptions are for impact on population and urban areas, where Namibia is ranked 22 out of 29.

Walvis Bay is the big issue
Oranjemund, Luderitz and Swakopmund are less problematic.

Walvis Bay with 1m sea level rise.
Flooding in the Kuiseb estuary.

Vulnerable Sandspits

Sandwich Harbour
Breach and Wetland Flood

Baia dos Tigres 11km
Breach and Exposed Coast

New Defences for Pelican Point

- Worst Case Storm on the exposed coast will have swash run up in excess of 4m, which will swamp the Pelican Point Sandspit and possibly lead to a permanent breach.
- Coastal defences would involve extensive engineering studies with the possibilities of sand nourishment, groynes, rock revet units and sand-filled geo-textile shore protection
- Theron 2007

Walvis Bay on a Sheltered Coast

Port Diagram Walvis Bay

Coastal defences would need to be raised as the sea level rises. In 2030 sea level rise of 20cm will be accompanied by coastal set back of up to 100m within the town. Additional coastal defences may well be needed

Walvis Bay on an Exposed Coast

- With Pelican Point gone, the town and harbour of Walvis Bay would be exposed to waves from the open sea.
- Additional run up of 108cm would be expected from waves on an annual basis, and 156cm from a hundred year storm.
- In latter case, the town would need protection at least to a level of LLD+276cm to prevent over 500m of coastal erosion and serious flooding.
- Costs would be very high.

Polar Ice Melt and Walvis Bay

In this scenario, sea level rise would gradually reach several metres above the present levels.

- Pelican Point would definitely be lost.
- Managed retreat rather than coastal defence becomes the preferred option.
- The harbour and its transport services must be continually rebuilt on higher ground.

Polar Ice Melt and Walvis Bay

- In this scenario, sea level rise would gradually reach several metres above the present levels.
- The town of Walvis Bay will likely be relocated.
- Fresh water will become a problem as the wells on the Kuiseb River become contaminated.
- Relocate upriver?
- **Risk assessment and forward planning needed.**

A SEA LEVEL RISE ASSESSMENT FOR THE COAST OF NAMIBIA

Thank You!

Lucinda Fairhurst



Lucindafairhurst@gmail.com

P.O. Box 474,
Eppindust,
Cape Town,
7475,
RSA



Sea Level Rise: Predicted Damage to Property & Infrastructure

Presented by:
Danie Nel
Lithon Project Consultants

24 July 2009



1. SUMMARY OF DIFFERENT SCENARIOS

- **PRESENT DAY WORST CASE**
 - 100 year storm: different impacts in different areas
 - Sheltered, exposed and very exposed environments
 - Sudden occurrences
- **YEAR 2030 SCENARIO**
 - Storm sea levels very close to current 100 year storm levels
 - Increased frequency and severity
- **INCREASING GHGs AND POLAR ICE SHEET MELT**
 - Extreme increases in sea levels
 - Eventual catastrophic sea level rise
 - Scenarios develop over long time spans

2. BASIC DEFINITIONS (cont.)

- Scenario planning
 - Basis for scenario selection
 - Scenario 1: 100-year storm, present day
 - Scenario 2: 2030
 - Scenario 3: Three atmospheric GHG concentration levels, dates unknown:
 - 350ppm, 550ppm and 750ppm CO₂
- Methodology for impact calculations
 - Basis for methodology selection
 - Directly and indirectly affected properties

Presentation Overview

- Summary of different scenarios
- Basic definitions
- Predicted impacts in
 - Henties Bay
 - Swakopmund
 - Walvis Bay
 - Luderitz

2. BASIC DEFINITIONS

- Uncertainty
- Storms vs. sea level rise
 - (Cost vs. loss)
- Financial / capital impacts vs. economic impacts
- Foregone opportunities
- Scarcity and scarcity value
- Risk (perceived risk, true risk and fear)
- Timelines
- Infrastructure planning and capital projects

3. Impacts: Henties Bay



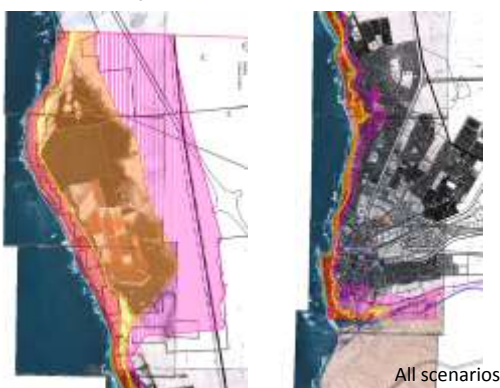
3. Impacts: Henties Bay

- **Scenario 1 (2009, sea level at 2009 mean sea level + 6m storm level)**
Apparently the dune face area of Hentiesbay (a pure dune shoreline, with some rocky or mixed areas) should be able to withstand storm conditions to a high degree.
 - Possible monetary impact:
 - N\$183mil (110 properties)
 - No damage to road infrastructure
 - Very minor damage to general water and sewer infrastructure
 - Very minor damage to general electrical infrastructure
 - Damage or interruption to a small number of businesses
- **Scenario 2 (2030, sea level at 2009 mean sea level + 6m level)**
 - Possible monetary (year 2009 equivalent) impact:
 - N\$341mil (205 properties)
 - Same extent of damage to other sectors as above

3. Impacts: Henties Bay

- Following scenarios based on 2030 level of growth:
- **Scenario 3a (sea level at 2009 mean level + 1m rise + 6m storm level)**
 - Possible monetary (year 2009 equivalent) impact: N\$341mil (205 properties)
 - **Scenario 3b (2009 mean sea level + 2m rise + 6m storm level)**
 - Possible monetary impact : N\$596mil (358 properties)
 - **Scenario 3c (2009 mean sea level + 10m rise)**
 - Possible monetary impact : N\$894mil (537 properties)
 - **Other sectors:**
 - Increasing levels of damage with each scenario
 - Total costs of these damages are outweighed by possible damage to property
 - Tourism will be mostly unaffected, but sports fishing is at risk!

4. Impacts: Swakopmund



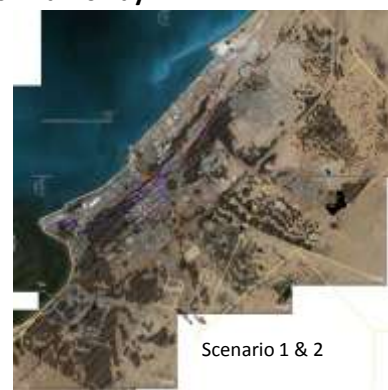
4. Impacts: Swakopmund

- **Scenario 1 (2009, sea level at 2009 mean sea level + 4m storm level)**
An exposed environment, Swakopmund is fortunately located on a fast rising slope the isolates most of the town from sea impacts.
 - Possible monetary impact:
 - N\$709mil (260 properties)
 - Minor damage to road infrastructure (salt and tar roads)
 - Minor damage to general water and sewer infrastructure
 - Minor damage to general electrical infrastructure
 - Damage or interruption to a small number of businesses
- **Scenario 2 (2030, sea level at 2009 mean sea level + 4m level)**
 - Possible monetary (year 2009 equivalent) impact:
 - N\$870mil (320 properties)
 - Same extent of damage to other sectors as above

4. Impacts: Swakopmund

- Following scenarios based on 2030 level of growth:
- **Scenario 3a (sea level at 2009 mean level + 1m rise + 4m storm level)**
 - Possible monetary (year 2009 equivalent) impact: N\$1bil (420 properties)
 - **Scenario 3b (2009 mean sea level + 2m rise + 4m storm level)**
 - Possible monetary impact : N\$1.1bil (550properties)
 - The Swakopmund salt works is extensively damaged
 - **Scenario 3c (2009 mean sea level + 10m rise)**
 - Possible monetary impact : N\$2.9bil (1600 properties)
 - **Other sectors:**
 - Increasing levels of damage with each scenario; some municipal bulk infrastructure is likely affected by the latter scenarios
 - Total costs of these damages are outweighed by possible damage to property
 - More businesses and organizations will be affected
 - Regional electricity should be unaffected
 - Tourism should be resilient to most changes

5. Impacts: Walvis Bay



5. Impacts: Walvis Bay



5. Impacts: Walvis Bay



5. Impacts: Walvis Bay



5. Impacts: Walvis Bay

- **Scenario 1 (2009, sea level at 2009 mean sea level + 1.5m storm level)**
Walvis Bay is considered a sheltered environment due to the Pelican Point peninsula. This natural feature is currently already at risk though and most of Walvis Bay is a very low lying area.
 - Possible monetary impact:
 - N\$642mil (530properties)
 - Minor damage to road infrastructure (salt and tar roads)
 - Minor damage to general water and sewer infrastructure
 - Minor damage to general electrical infrastructure
 - Damage or interruption to a number of businesses
- **Scenario 2 (2030, sea level at 2009 mean sea level + 1.5m level)**
 - Possible monetary (year 2009 equivalent) impact:
 - N\$1.3bil (985 properties)
 - Same extent of damage to other sectors as above, notably the salt works

5. Impacts: Walvis Bay

- Following scenarios based on 2030 level of growth:
- **Scenario 3a (sea level at 2009 mean level + 1m rise+1.5m storm level)**
 - Possible monetary (year 2009 equivalent) impact: N\$22bil (17,000 properties)
 - The salt works is extensively damaged / destroyed
 - **Scenario 3b (2009 mean sea level + 2m rise + 1.5m storm level)**
 - Possible monetary impact : N\$25bil (19,000 properties)
 - **Scenario 3c (2009 mean sea level + 10m rise)**
 - Possible monetary impact : N\$26bil (20,000+ properties)
 - Port operations ceased
 - **Other sectors:**
 - Increasing levels of damage with each scenario; some municipal bulk infrastructure is likely affected by the latter scenarios
 - Total costs of these damages outweighed by possible damage to property
 - Many businesses, some very large, and organizations will be affected
 - Regional electricity should be mostly unaffected

6. Impacts: Luderitz



6. Impacts: Luderitz

- **Scenario 1 (2009, sea level at 2009 mean sea level + 1.5m storm level)**
Luderitz is considered a sheltered environment. Additionally the town lies on "high ground" protecting it from severe impacts.
 - Possible monetary impact:
 - N\$133mil (80properties)
 - Almost no damage to road infrastructure
 - Very minor damage to general water and sewer infrastructure
 - Very minor damage to general electrical infrastructure
- **Scenario 2 (2030, sea level at 2009 mean sea level + 1.5m level)**
 - Possible monetary (year 2009 equivalent) impact:
 - N\$248mil (149 properties)
 - Same extent of damage to other sectors as above, notably the salt works

6. Impacts: Luderitz

Following scenarios based on 2030 level of growth:

- **Scenario 3a (sea level at 2009 mean level + 1m rise+1.5m storm level)**
 - Possible monetary (year 2009 equivalent) impact: N\$273mil (164 properties)
- **Scenario 3b (2009 mean sea level + 2m rise + 1.5m storm level)**
 - Possible monetary impact : N\$327mil (196 properties)
- **Scenario 3c (2009 mean sea level + 10m rise)**
 - Possible monetary impact : N\$491mil (295 properties)
 - Port operations severely affected or ceased
- **Other sectors:**
 - Increasing levels of damage with each scenario; some municipal bulk infrastructure is likely affected by the latter scenarios, but on a small scale
 - A number of businesses along the shoreline may be affected

7. Impacts: Interurban areas



Henties Bay

7. Impacts: Interurban areas



Swakopmund

7. Impacts: Interurban areas



Walvisbay

Thank you

- Thank you for your valuable time
- Questions?

Presented by:
Danie Nel
Lithon Project Consultants

A sea level rise assessment for the coast of Namibia

An ecosystem and governance approach



lucinda.fairhurst@gmail.com

P.O. Box 474,
Eppindus,
Cape Town,
7475,
RSA

Storm surges

Mean sea level rise

The most devastating impacts are likely to be associated with changes in **extreme sea levels** resulting from the passage of storms, especially as more intense tropical and extra-tropical storms are expected.



- Increased erosion
- Flooding
- Salt water intrusion
- Shoreline retreat

- Dynamic systems
 - Geomorphology and oceanography
 - Wetlands (82% - World Bank, 2009)
 - Marine systems
 - Terrestrial systems

- Replenishment of groundwater
- Oxygen production
- Flood attenuation
- Atmospheric carbon sinks
- Filtering of run-off and air pollution
- Tourism draw card
- Provision of medicinal and other natural products
- Recreational, cultural, educational, spiritual values
- Artisanal and subsistence fishing and agriculture

- Fishing industry
 - offshore commercial fishery 2nd largest contributor to GDP
 - In-shore fishery
 - Recreational fishing
- Impacts:
 - Coastal/marine interface
 - Primary production
 - Spawning and nursery grounds
 - Longer term: Changes in upwelling dynamics

•Coastal Errosion

•Salt water intrusion

•Raised water tables

•Storm surges

Coastal Errosion

- Intertidal zone
 - Barnacles
 - Limpets
 - Rock lobster
 - Algae

Storm events will not assist replenishment

- Walvis Bay – RICH IN BIODIVERSITY

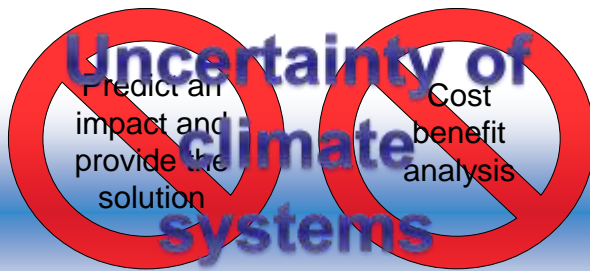
Saline Intrusion Industry:

- Wetlands
- Low-lying lands
- Estuaries
- Aquifers
- Fisheries
- Tourism
- Agriculture

Impacts:

- Increased Salinity
- Impair water quality
- Alter tidal ranges
- Sediment deposition
- Nursery habitats – fish sp., molluscs

<i>Improve policy planning and legislation</i>	<i>Improve the institutional framework</i>	<i>Increase public participation and build capacity</i>
Legislate	Increase horizontal integration	Build institutional capacity
Improve content of legislation	Increase vertical integration	Increase public involvement and decrease inequity
Improve instruments for policy planning	Improve the institutional framework and pursue decentralisation	Improve knowledge and education



How do we value ecosystem goods and services?

Over what time frame?

Do we account for future generations?

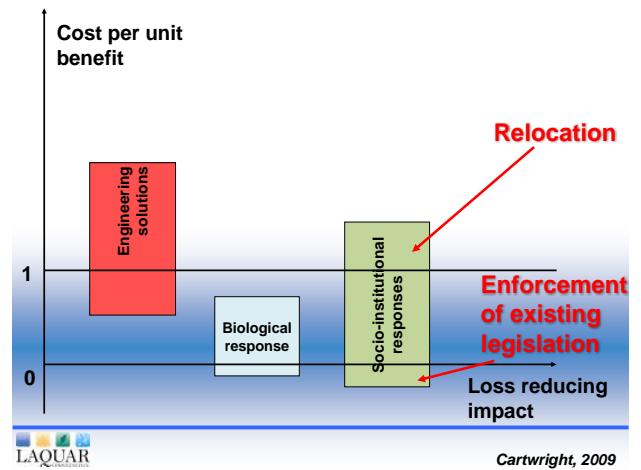


How do we separate the impacts and benefits?

Do we apply a discount rate?



- **Direct impact:**
 - Financial cost of replacing/rebuilding infrastructure.
- **Indirect impacts:**
 - Opportunity cost: cost of foregone development
 - Induced loss
 - Maladaptation cost: often makes it worse
- **Maladaptation impacts:**



Adaptation = “a response to the effects of climate change, to help reduce damage in the short-term, regardless of any longer term changes in the climate” (IPCC).



- *Reduce vulnerability* in the face of uncertain future events, ie: developing early warning systems for natural disasters.
- *Enhance the resilience* of infrastructures to cope with climatic events, ie: peace-building activities and the diversification of livelihoods.



Sea-level rise in Namibia

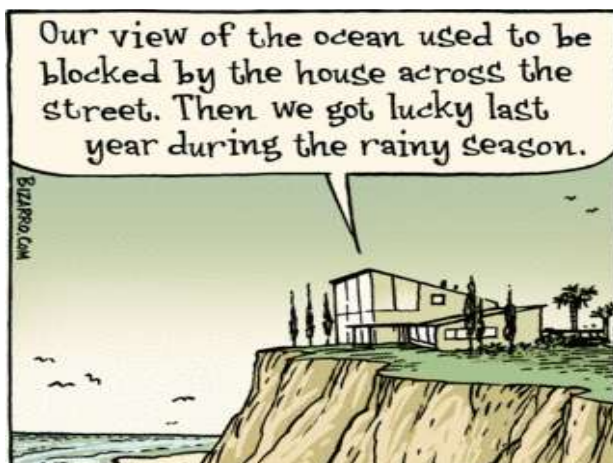
- Historically, Namibia in line with global average.
- Projections for “events” and **inundation** - Mean sea-level (melting land ice, thermal expansion), storms.

So what.....?

Sea level rise will impose risks - environmental risks include social, financial and governance risks

Environmental risk is subjective

- Risk of what?
- Risk for whom?
- Risk when?
- Risk where?



Adaptive capacity

Ability of a system to evolve in order to accommodate climate changes or to expand the range of variability with which it can cope. (IPCC)



No regrets options

- Not directly linked to SLR but worth pursuing due to the **systemic benefits** they deliver.
- No additional funding.
 - No not further degrade wetland and estuaries
 - Integrate SLR scenarios in future planning
 - No further development in low-lying areas



Additional options

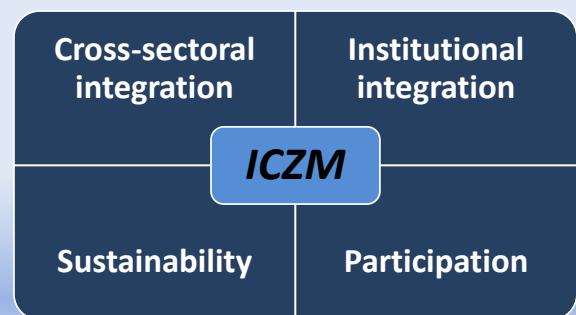
Require new investment, new approaches and **trade-offs** and costs.

- Engineering solutions
- Biological solutions
- Socio-institutional responses



Socio-institutional responses

- Best managed in accordance with principles of Integrated Coastal Zone Management (ICZM).
- Coastal policies must all be set **“within the limits set by natural dynamics”** = ecosystem approach.



What can Namibia do?

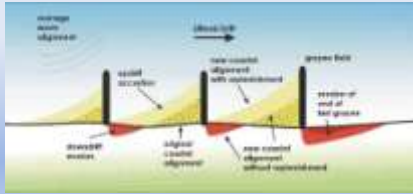
- “No regrets” approaches – not directly linked to sea-levels but assist in coping with sea-level rise and many other things
 - Consider SLR in future planning
 - Don’t develop wetlands and estuaries
 - Don’t reclaim land
 - Alleviate poverty

“Additional” approaches - deliberate decisions and trade-offs

- Managed retreat
- Hold the line – Port, some roads, sub-stations–sea walls, dolosse, off-shore reefs, groynes, barrages
- Combined approaches
 - Physical: Beach and dune replenishment,
 - Biological: Coastal vegetation, kelp, beach kelp, rehabilitate estuaries and wetlands
 - Institutional approaches: Vulnerability assessments, early warning systems, risk communication, insurance, set-backs, education, measurements

Hold the line: Groyne field

- http://www.environment.sa.gov.au/coasts/images/groyne_diagram.jpg



Hold the line: Groyne field



http://www.travel-in-portugal.com/photos/data/media/4/beach_groynes.jpg

Hold the Line: Barrage



- http://www.blewbury.co.uk/energy/images/Rance_tidal_power_plant.jpg

Hold the Line: Gabions

Appropriate locations	Sandy beach sites suffering periodic moderate to severe erosion where backshore assets are at risk. Useful for estuary bank protection.
Costs	Moderate, but require maintenance
Effectiveness	Well placed gabions provide reasonable fixed defences, but have a limited life of 5-10 years due to deterioration of the baskets.
Benefits	Useful solution where armour rock is considered inappropriate or too costly. Various forms available.
Problems	Limited life, leading to unsightly and hazardous wire baskets along beach and the release of non-indigenous cobbles to the beach system. Wire affected by saltwater, vandalism and abrasion by trampling or gravel beach impacts.



<http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/images/plate-a16.jpg>



http://www.rareconservation.org/blog/wp-content/photos/Sibogo__the_village_on_stilts.jpg



http://3.bp.blogspot.com/_jISmTPwJZy/SV0vZ2Ye1y/AAAAAAAAAE9o/Bk4Vh_sLfo/s400/38.gif

Combined, Physical: Beach replenishment



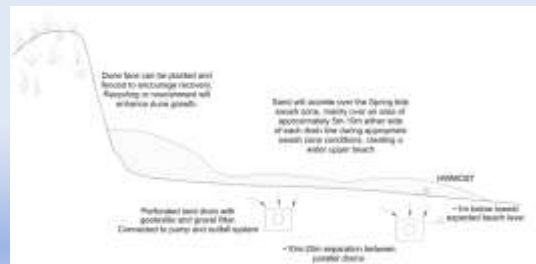
<http://www.havant.gov.uk/images/shingle-web.jpg>

Artificial Reefs



<http://saltwaterfishing.sc.gov/photogallery/reefcone.jpg>

Reducing salt water intrusion



Healthy natural ecosystem approach



A wide range of various ecosystems such as river deltas, river flood plains, peat bogs, mangroves, marshes, tundra, lagoons, and swamps are vital to ecological functions that keep the world going

Combined, Biological: Coastal Vegetation



<http://www.flmnh.ufl.edu/fish/Gallery/Description/Peray/kelpnoaa.JPG>

Goal is 'adapting well,
not being well adapted'
(UKCIP)



lucindafairhurst@gmail.com

P.O. Box 474,
Eppindurst,
Cape Town,
7475,
RSA

11.4. Recommendations

**SEA LEVEL RISE PROJECT WORKSHOP
MINISTRY OF ENVIRONMENT AND TOURISM
ATLANTIC HOTEL, 24 JULY 2009-08-06**

The consulting team made four presentations covering different sections of the draft report:

- 1) Projected changes in sea level and storm surges
- 2) Impacts to property and infrastructure
- 3) Environmental impacts and issues related to governance
- 4) Strategies and options for adapting to sea level rise

After the presentations were completed, and stakeholders' questions and comments addressed, the workshop participants were asked to provide their recommendations and comments regarding possible adaptation strategies for Namibia. All of the recommendations developed at the workshop are relevant to the recommended options for adaptation that are included in Section 8 of the report, Adaptation Strategy Options. The following is a summary of the stakeholders' ideas, and how they correlate with the recommendations in Section 8.

- 1) The findings of this study should be continued to be distributed to planners, property developers, public decision-makers, insurance companies, coastal businesses, not-for-profit organisations and residents. Insurance companies, in particular should be alerted about sea level rise projections so that the projections can be factored into insurance plans.

This recommendation is consistent with two of the recommended adaptation options provided in the report regarding effective communication campaigns and insurance market correction.

- 2) Donors should encourage that any information generated from the projects they fund be made freely available to other projects and stakeholders.

This recommendation was the conclusion of a discussion about how stakeholders, organisations and projects sometimes attempt to prevent or block others from obtaining important plans, reports and data as a result of the competition that sometimes exists amongst professionals and institutions. This recommendation is relevant to the recommended options in the report regarding research and monitoring and effective communication campaigns.

- 3) The types of sea level data recorded by the Ministry of Fisheries, NamPort and other institutions should be standardised. Furthermore, consideration should be given to establishing a national office that is responsible for collecting, storing and distributing data and information related to sea level rise.

This recommendation is relevant to the recommended options in the report regarding research and monitoring and effective communication campaigns. Research, monitoring and communication about sea level rise in Namibia will only be effective if relevant information is effectively collected, stored and made available to researchers and stakeholders.

- 4) The predictions for sea level rise should be incorporated into town planning and zoning maps, and should be considered within environmental impact assessments and strategic environmental assessments that are prepared for future / potential coastal development projects.

This recommendation is relevant to the recommended option in the report regarding applying legislation and regulations to limit development within land areas that are potentially at risk of sea level rise and storm surges.

- 5) Sea level rise should factor into a White Paper on Coastal Zone Management.

This recommendation is relevant to the recommended option in the report regarding applying legislation and regulations because effective policy is a prerequisite for effective legislation and regulation.

- 6) The boundaries of sea level rise projections should be delineated in the field by municipalities or the national government.

Again, this recommendation is relevant to the recommendation in the report regarding applying legislation and regulations.

- 7) The project report should mention that sea level rise adaptation plans are local in nature.

This concept is indeed covered in Section 8 of the report and was stated by the consulting team at the onset of the group discussion.

- 8) Environmental legislation needs to be advanced as part of an adaptation strategy to increase the resilience of ecosystems to the impacts of sea level rise.

This recommendation is relevant to the recommendation in the report regarding applying legislation and regulations.