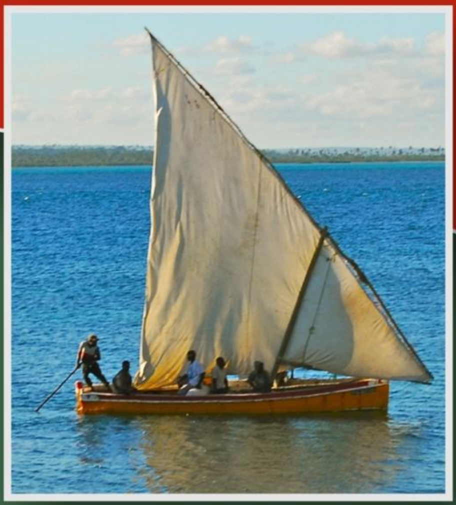
RESPONDING TO CLIMATE CHANGE IN MOZAMBIQUE

REPUBLIC OF MOZAMBIQUE
MINISTRY OF STATE ADMINISTRATION
NATIONAL INSTITUTE OF DISASTER MANAGEMENT

Instituto Nacional de
Gestão de Calamidades



THEME 3

National Institute for Disaster Management (INGC)
PHASE II

THEME 3
Preparing Cities

October 2012

McKinsey & Co.

Contact details for correspondence:

McKinsey & Co.

Diogo_Almeida_Pinheiro@mckinsey.com
Marcel_Normann@mckinsey.com

Tel: +49 40 3612 1366
Fax: +49 40 3612 1367

Project Director: Joao Tiago MM Ribeiro
Project Coordinator: Barbara van Logchem
Science Coordinator: Antonio J Queface

Report to be referenced as:

McKinsey & Co. 2012. *Responding to climate change in Mozambique: Theme 3: Preparing cities.* Maputo: INGC.

Report layout:
DTP Solutions
Contact details: magdelvdm@gmail.com

CONTENTS

SLIDE 1

INGC Phase II – “Preparing Cities”

Final report
September 2011

SLIDE 2

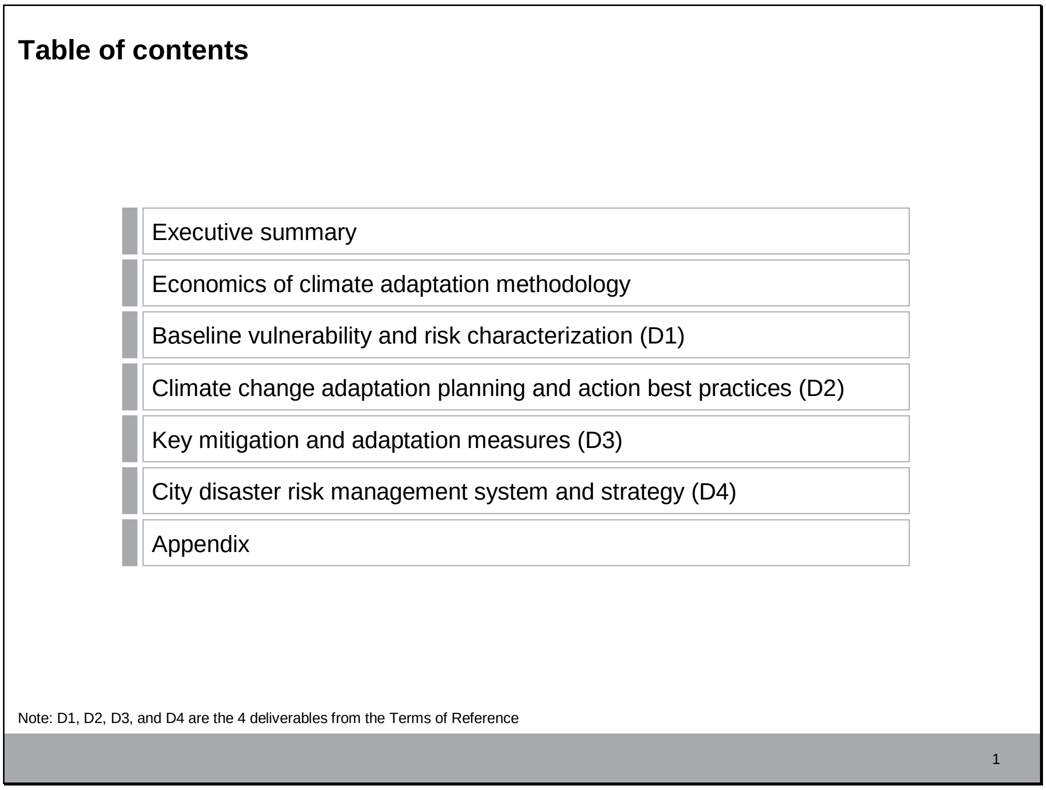


Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 3

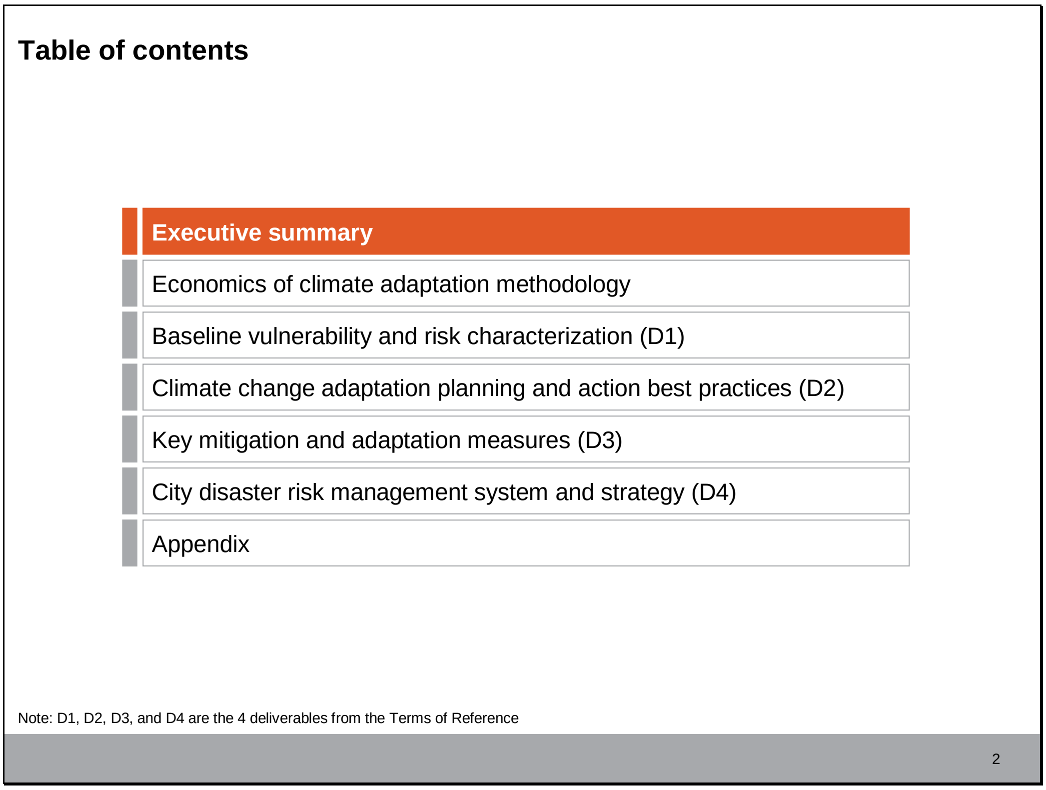
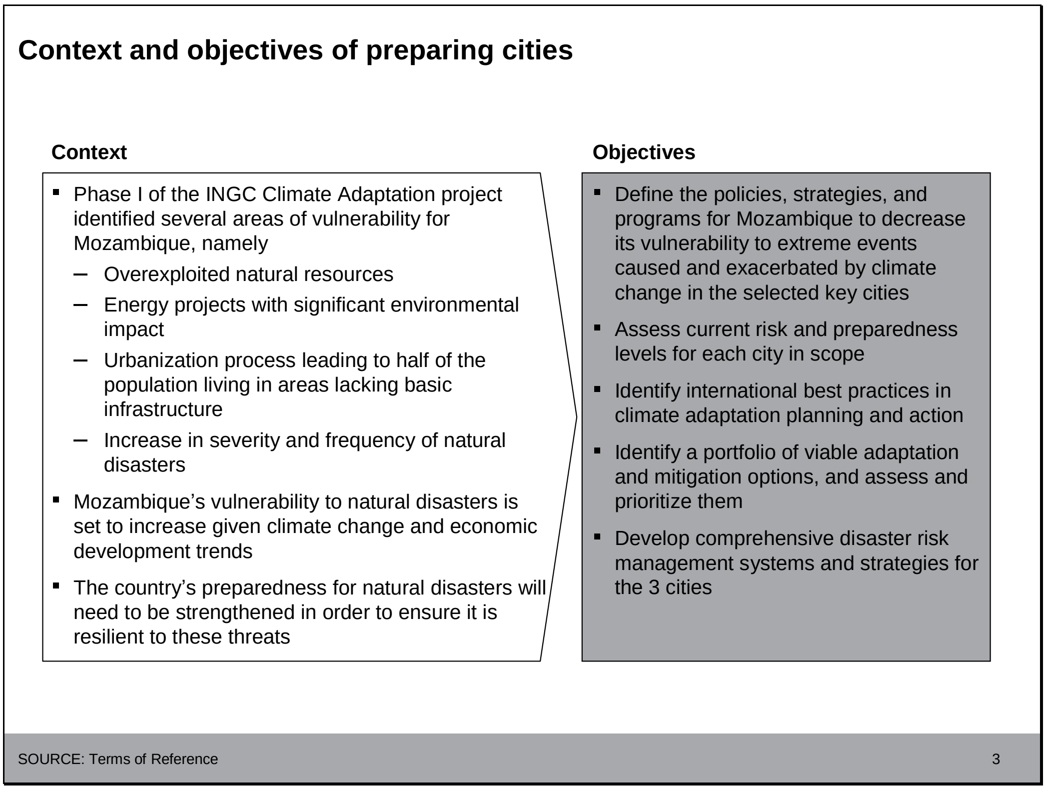


Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 4



Context and objectives of preparing cities

Context

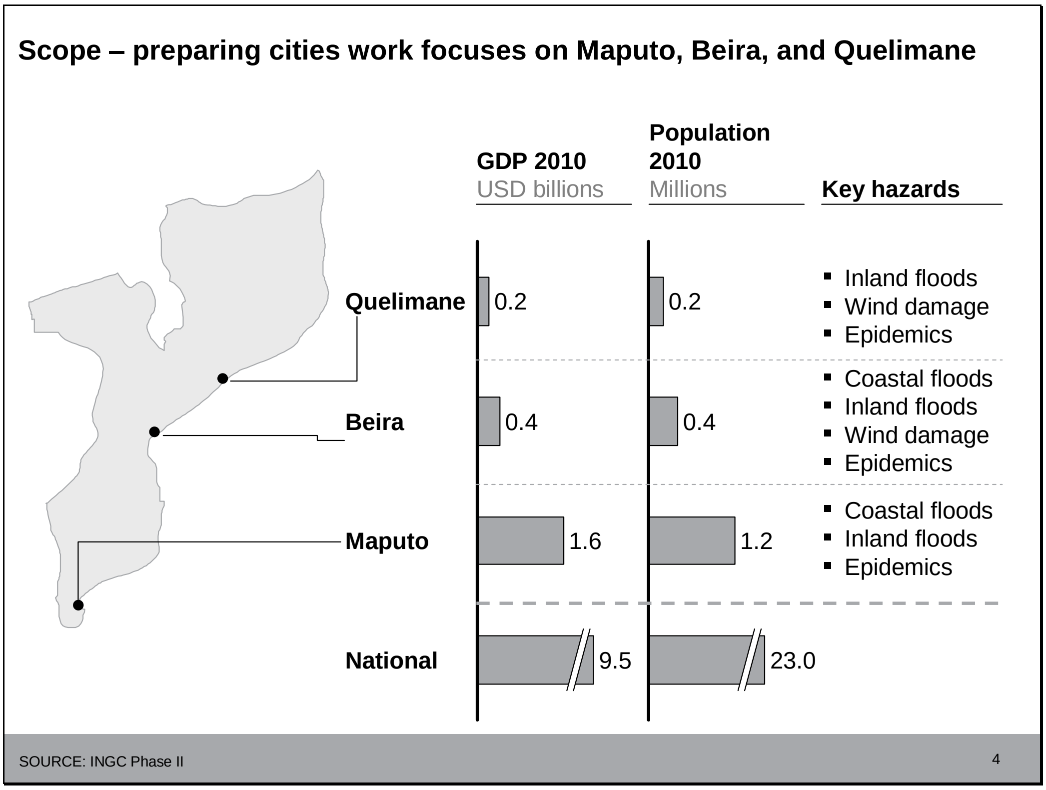
- Phase I of the INGC Climate Adaptation project identified several areas of vulnerability for Mozambique, namely
  - Overexploited natural resources
  - Energy projects with significant environmental impact
  - Urbanization process leading to half of the population living in areas lacking basic infrastructure
  - Increase in severity and frequency of natural disasters
- Mozambique's vulnerability to natural disasters is set to increase given climate change and economic development trends
- The country's preparedness for natural disasters will need to be strengthened in order to ensure it is resilient to these threats

Objectives

- Define the policies, strategies, and programs for Mozambique to decrease its vulnerability to extreme events caused and exacerbated by climate change in the selected key cities
- Assess current risk and preparedness levels for each city in scope
- Identify international best practices in climate adaptation planning and action
- Identify a portfolio of viable adaptation and mitigation options, and assess and prioritize them
- Develop comprehensive disaster risk management systems and strategies for the 3 cities

SOURCE: Terms of Reference

SLIDE 5

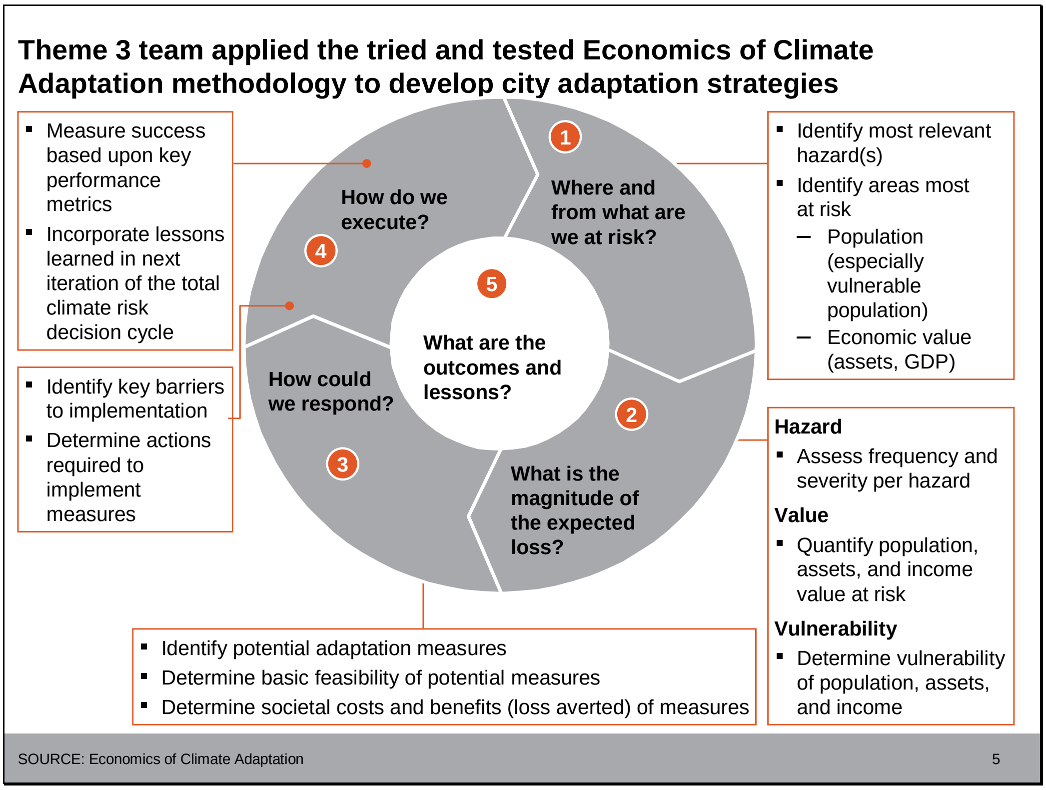


Scope – preparing cities work focuses on Maputo, Beira, and Quelimane

	GDP 2010 USD billions	Population 2010 Millions	Key hazards
Quelimane	0.2	0.2	Inland floods Wind damage Epidemics
Beira	0.4	0.4	Coastal floods Inland floods Wind damage Epidemics
Maputo	1.6	1.2	Coastal floods Inland floods Epidemics
National	9.5	23.0	

SOURCE: INGC Phase II

SLIDE 6



Theme 3 team applied the tried and tested Economics of Climate Adaptation methodology to develop city adaptation strategies

- Identify most relevant hazard(s)
- Identify areas most at risk
  - Population (especially vulnerable population)
  - Economic value (assets, GDP)

Hazard
- Assess frequency and severity per hazard

Value
- Quantify population, assets, and income value at risk

Vulnerability
- Determine vulnerability of population, assets, and income

- Identify potential adaptation measures
- Determine basic feasibility of potential measures
- Determine societal costs and benefits (loss averted) of measures

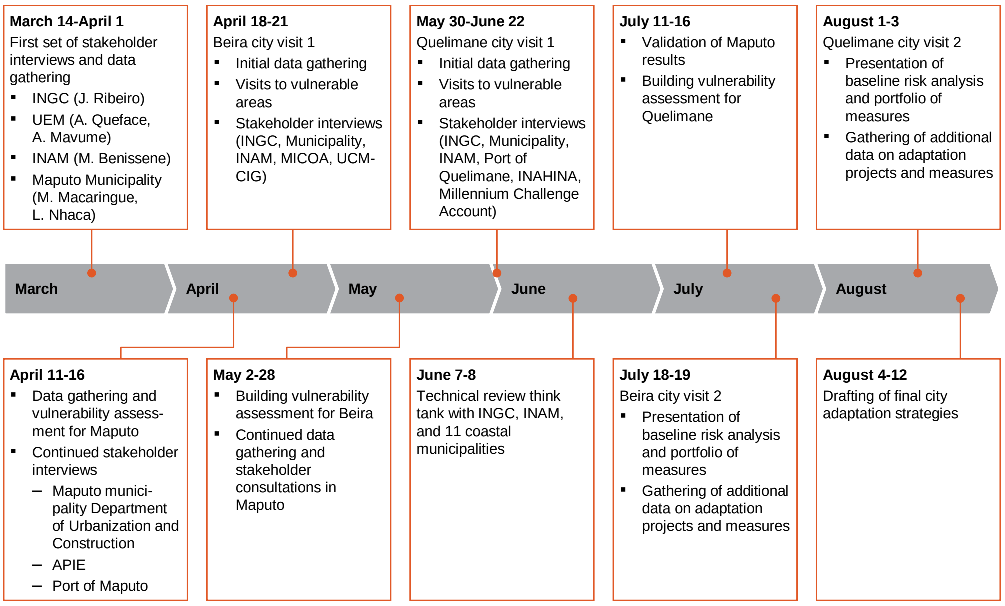
- Identify key barriers to implementation
- Determine actions required to implement measures

- Measure success based upon key performance metrics
- Incorporate lessons learned in next iteration of the total climate risk decision cycle

SOURCE: Economics of Climate Adaptation

SLIDE 7

City adaptation strategies were developed leveraging city visits, best practices, and extensive stakeholder consultations



March 14-April 1
First set of stakeholder interviews and data gathering
- INGC (J. Ribeiro)
- UEM (A. Queface, A. Mavume)
- INAM (M. Benissene)
- Maputo Municipality (M. Macaringue, L. Nhaca)

April 18-21
Beira city visit 1
- Initial data gathering
- Visits to vulnerable areas
- Stakeholder interviews (INGC, Municipality, INAM, MICOA, UCM-CIG)

May 30-June 22
Quelimane city visit 1
- Initial data gathering
- Visits to vulnerable areas
- Stakeholder interviews (INGC, Municipality, INAM, Port of Quelimane, INAHINA, Millennium Challenge Account)

July 11-16
- Validation of Maputo results
- Building vulnerability assessment for Quelimane

August 1-3
Quelimane city visit 2
- Presentation of baseline risk analysis and portfolio of measures
- Gathering of additional data on adaptation projects and measures

April 11-16
- Data gathering and vulnerability assessment for Maputo
- Continued stakeholder interviews
  - Maputo municipality Department of Urbanization and Construction
  - APIE
  - Port of Maputo

May 2-28
- Building vulnerability assessment for Beira
- Continued data gathering and stakeholder consultations in Maputo

June 7-8
Technical review think tank with INGC, INAM, and 11 coastal municipalities

July 18-19
Beira city visit 2
- Presentation of baseline risk analysis and portfolio of measures
- Gathering of additional data on adaptation projects and measures

August 4-12
Drafting of final city adaptation strategies

SOURCE: INGC Phase II Theme 3

SLIDE 8

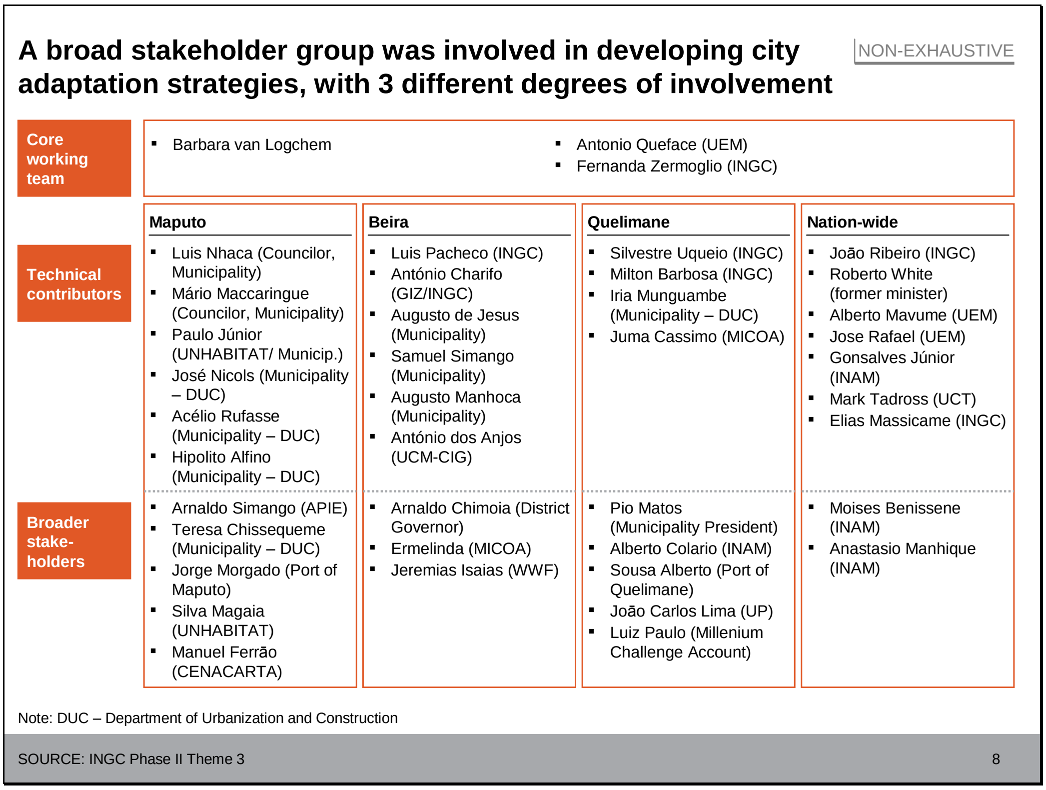
On September 19 the key recommendations were reviewed by the CCGC

Participants
- CCGC
  - Prime Minister
  - Minister MAE
  - Minister MNEC
  - Minister MA
  - Minister MICOA
  - Minister MMAS
  - Minister MD
  - Minister MIC
  - Minister MI
  - Minister MOPH
  - Minister MPD
  - Minister MF
  - Minister MS
  - Minister MEDU
  - Minister MRM
  - Minister MCT
  - Vice Minister MTC
  - General Manger INGC
- Presidents of key universities (UEM, UP, ISRI, ISPU, UDM, USTM, ISTEG, ISAP, ISCISA)

Content Presented
- Context and methodological overview for the Theme 3
- Vulnerability assessment for Maputo, Beira and Quelimane and implications for prioritization
- Definition of potential portfolio of financial and non-financial adaptation measures for each city
- Prioritization of measures for each city
- Overall cost and impact of proposed adaptation measures
- Integration into city strategy

Outcome
- Indentified measures are very important to protect these cities and need to be included into the municipal investment plans, according to the overall city investment strategy
- State budget is relatively thin and so measures need to be contingent to existin funding; positive cost-benefir measures, however, should be pushed trough as they are self-sustainable
- There already exists some degree of insurance on buildings, but these need to be widened to cover climate risks, but it makes more sense to consider this at a national level

SLIDE 9



A broad stakeholder group was involved in developing city adaptation strategies, with 3 different degrees of involvement

NON-EXHAUSTIVE

Core working team
- Barbara van Logchem
- Antonio Queface (UEM)
- Fernanda Zermoglio (INGC)

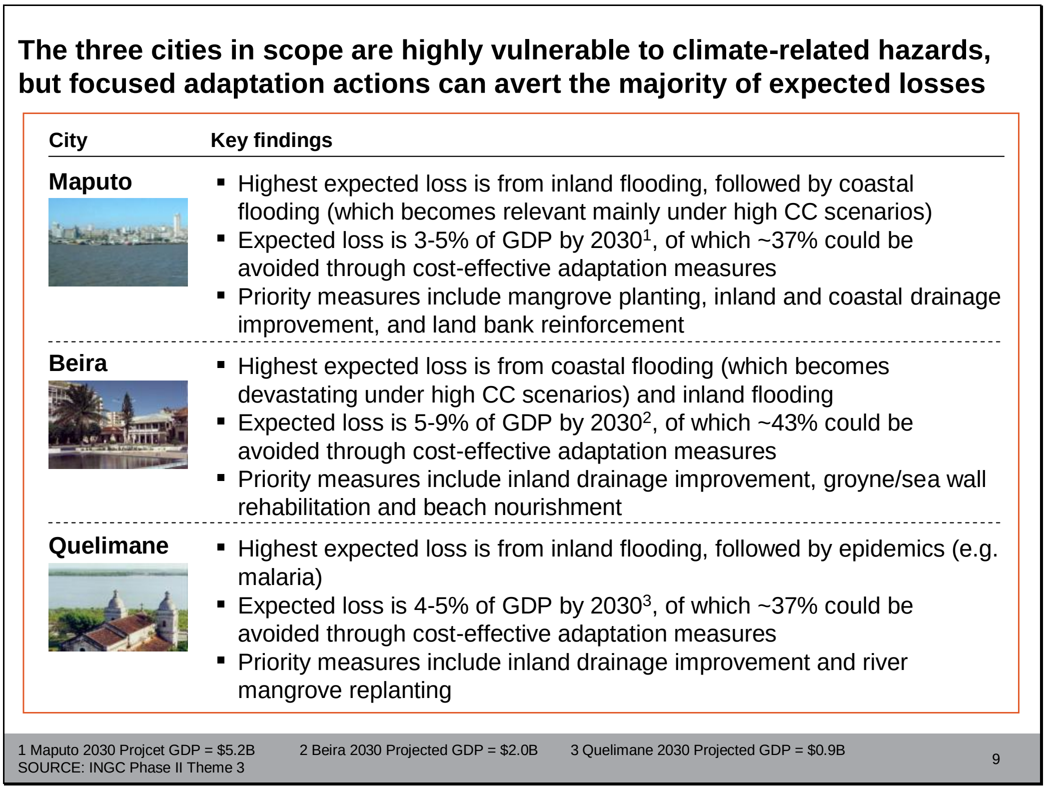
	Maputo	Beira	Quelimane	Nation-wide
Technical contributors	▪ Luis Nhaca (Councilor, Municipality) ▪ Mário Maccaringue (Councilor, Municipality) ▪ Paulo Júnior (UNHABITAT/ Municip.) ▪ José Nicols (Municipality – DUC) ▪ Acélio Rufasse (Municipality – DUC) ▪ Hipolito Alfino (Municipality – DUC)	▪ Luis Pacheco (INGC) ▪ António Charifo (GIZ/INGC) ▪ Augusto de Jesus (Municipality) ▪ Samuel Simango (Municipality) ▪ Augusto Manhoca (Municipality) ▪ António dos Anjos (UCM-CIG)	▪ Silvestre Upqueio (INGC) ▪ Milton Barbosa (INGC) ▪ Iria Munguambe (Municipality – DUC) ▪ Juma Cassimo (MICOA)	▪ João Ribeiro (INGC) ▪ Roberto White (former minister) ▪ Alberto Mavume (UEM) ▪ Jose Rafael (UEM) ▪ Gonsalves Júnior (INAM) ▪ Mark Tadross (UCT) ▪ Elias Massicame (INGC)
Broader stake-holders	▪ Arnaldo Simango (APIE) ▪ Teresa Chissequeme (Municipality – DUC) ▪ Jorge Morgado (Port of Maputo) ▪ Silva Magaia (UNHABITAT) ▪ Manuel Ferrão (CENACARTA)	▪ Arnaldo Chimoia (District Governor) ▪ Ermelinda (MICOA) ▪ Jeremias Isaias (WWF)	▪ Pio Matos (Municipality President) ▪ Alberto Colario (INAM) ▪ Sousa Alberto (Port of Quelimane) ▪ João Carlos Lima (UP) ▪ Luiz Paulo (Millenium Challenge Account)	▪ Moises Benissene (INAM) ▪ Anastasio Manhique (INAM)

Note: DUC – Department of Urbanization and Construction

SOURCE: INGC Phase II Theme 3

8

SLIDE 10



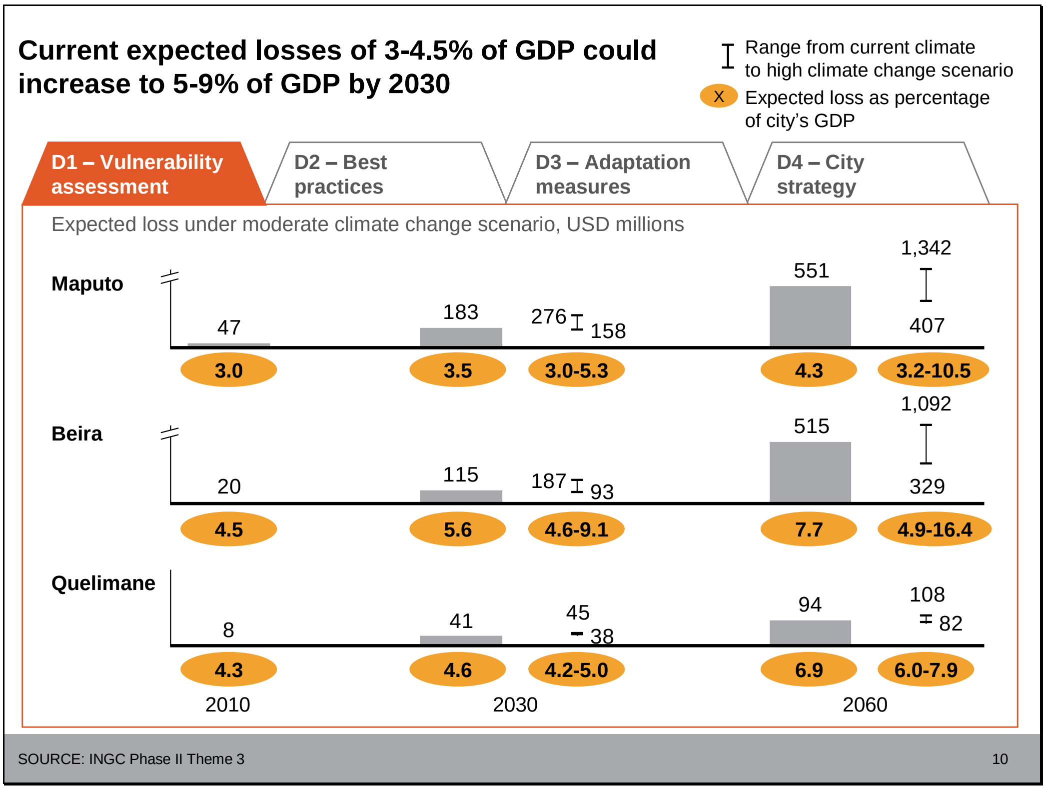
The three cities in scope are highly vulnerable to climate-related hazards, but focused adaptation actions can avert the majority of expected losses

City	Key findings
Maputo	▪ Highest expected loss is from inland flooding, followed by coastal flooding (which becomes relevant mainly under high CC scenarios) ▪ Expected loss is 3-5% of GDP by 2030^1, of which ~37% could be avoided through cost-effective adaptation measures ▪ Priority measures include mangrove planting, inland and coastal drainage improvement, and land bank reinforcement
Beira	▪ Highest expected loss is from coastal flooding (which becomes devastating under high CC scenarios) and inland flooding ▪ Expected loss is 5-9% of GDP by 2030^2, of which ~43% could be avoided through cost-effective adaptation measures ▪ Priority measures include inland drainage improvement, groyne/sea wall rehabilitation and beach nourishment
Quelimane	▪ Highest expected loss is from inland flooding, followed by epidemics (e.g. malaria) ▪ Expected loss is 4-5% of GDP by 2030^3, of which ~37% could be avoided through cost-effective adaptation measures ▪ Priority measures include inland drainage improvement and river mangrove replanting

1 Maputo 2030 Projcet GDP = $5.2B 2 Beira 2030 Projected GDP = $2.0B 3 Quelimane 2030 Projected GDP = $0.9B
SOURCE: INGC Phase II Theme 3

9

SLIDE 11



Current expected losses of 3-4.5% of GDP could increase to 5-9% of GDP by 2030

Ɪ Range from current climate to high climate change scenario

X Expected loss as percentage of city's GDP

D1 – Vulnerability assessment

D2 – Best practices

D3 – Adaptation measures

D4 – City strategy

Expected loss under moderate climate change scenario, USD millions

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 11:

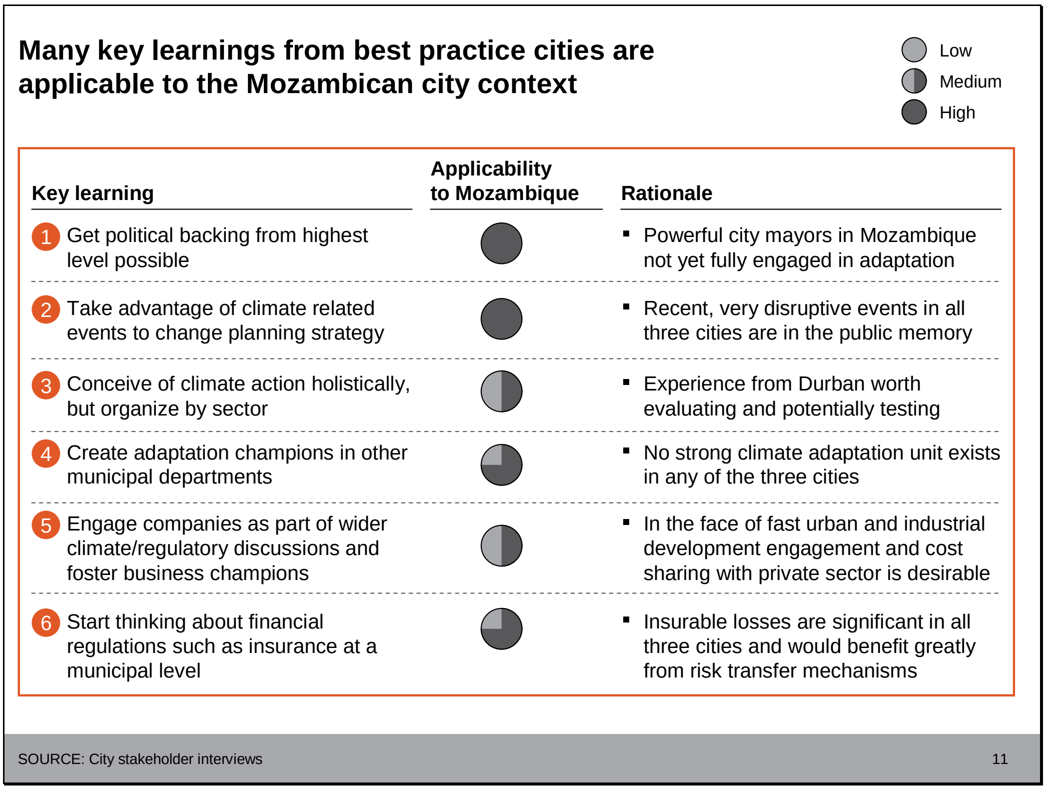
Overview of D1 - Vulnerability Assessment

Current GDP losses for each city due to climate change range from 3.0–4.5%, and are projected to expand up to 5-9% of GDP by 2030.

Losses due to climate change are charted for 2010, 2030, and 2060. The base case shown in grey for each year are the losses projected from the moderate climate change scenario, and the orange bubbles below show the losses as a percentage of each city's GDP. The ranges to the right of each grey bar show the projected losses from the other two climate scenarios, with the low bound at continuing the current climate and the high bound at impacts from the high climate change scenario.

The high bounds for each city's damages for 2030 give the 5-9% estimate for the worst case scenario.

SLIDE 12



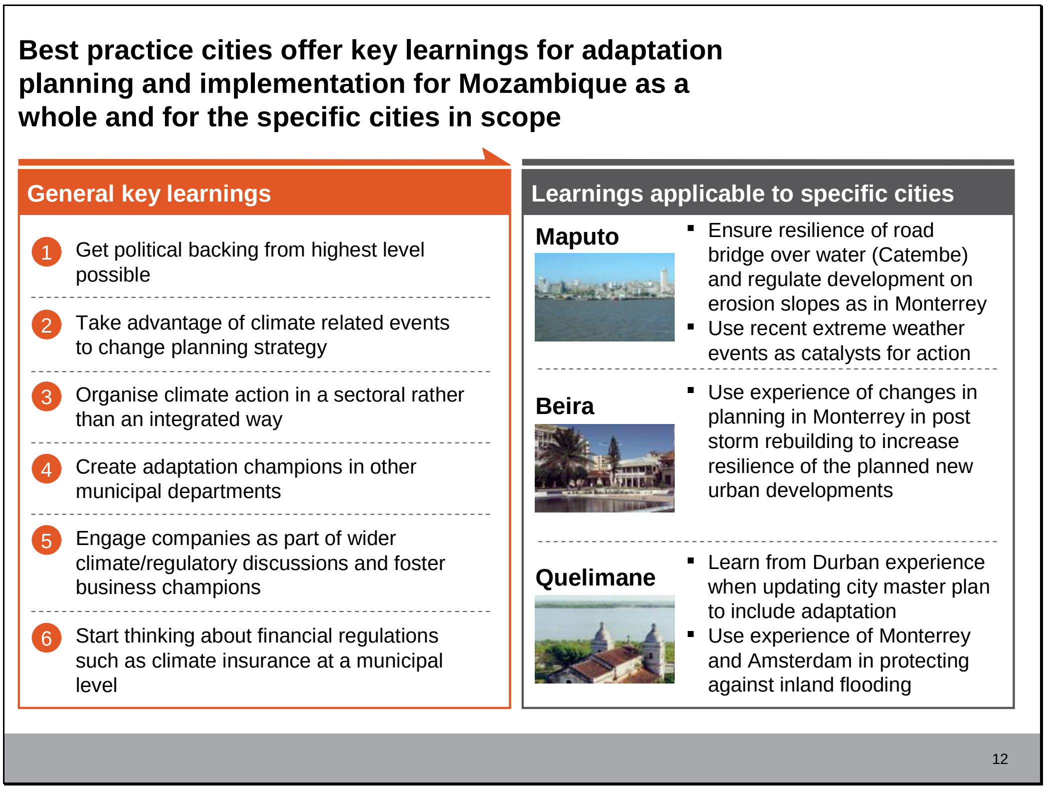
Many key learnings from best practice cities are applicable to the Mozambican city context

○ Low
◑ Medium
● High

Key learning	Applicability to Mozambique	Rationale
① Get political backing from highest level possible	●	▪ Powerful city mayors in Mozambique not yet fully engaged in adaptation
② Take advantage of climate related events to change planning strategy	●	▪ Recent, very disruptive events in all three cities are in the public memory
③ Conceive of climate action holistically, but organize by sector	◑	▪ Experience from Durban worth evaluating and potentially testing
④ Create adaptation champions in other municipal departments	◕	▪ No strong climate adaptation unit exists in any of the three cities
⑤ Engage companies as part of wider climate/regulatory discussions and foster business champions	◑	▪ In the face of fast urban and industrial development engagement and cost sharing with private sector is desirable
⑥ Start thinking about financial regulations such as insurance at a municipal level	◕	▪ Insurable losses are significant in all three cities and would benefit greatly from risk transfer mechanisms

SOURCE: City stakeholder interviews

SLIDE 13



Best practice cities offer key learnings for adaptation planning and implementation for Mozambique as a whole and for the specific cities in scope

General key learnings

① Get political backing from highest level possible

② Take advantage of climate related events to change planning strategy

③ Organise climate action in a sectoral rather than an integrated way

④ Create adaptation champions in other municipal departments

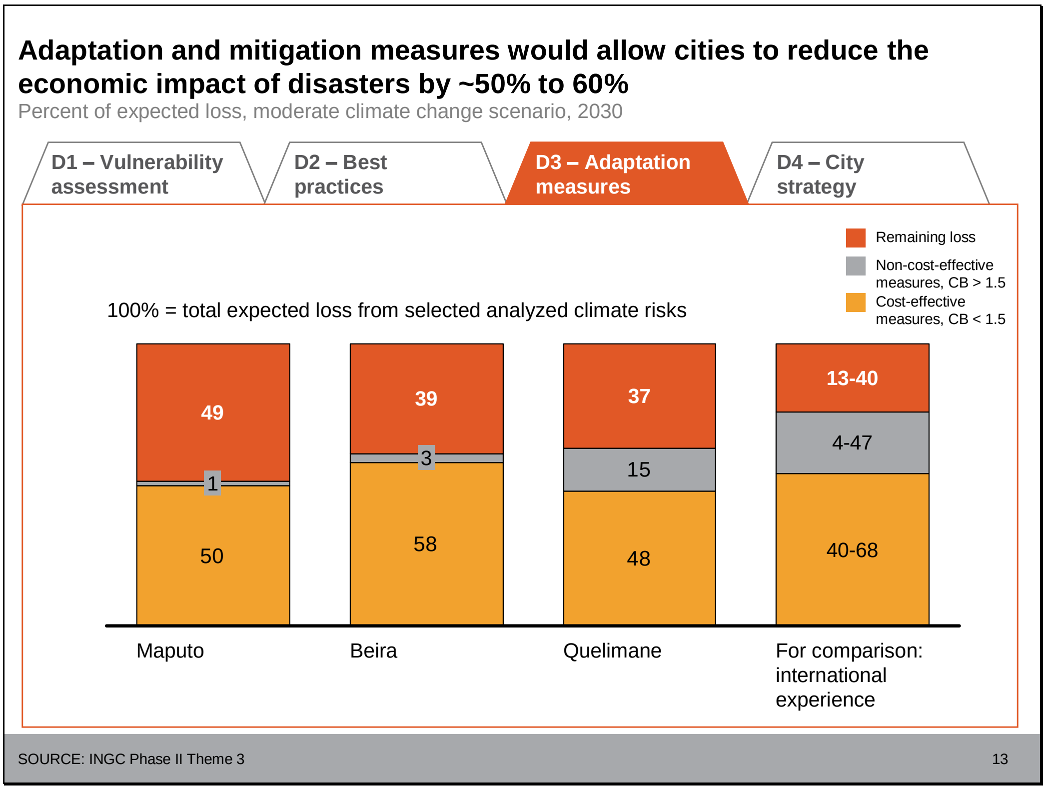
⑤ Engage companies as part of wider climate/regulatory discussions and foster business champions

⑥ Start thinking about financial regulations such as climate insurance at a municipal level

Learnings applicable to specific cities

Maputo	▪ Ensure resilience of road bridge over water (Catembe) and regulate development on erosion slopes as in Monterrey ▪ Use recent extreme weather events as catalysts for action
Beira	▪ Use experience of changes in planning in Monterrey in post storm rebuilding to increase resilience of the planned new urban developments
Quelimane	▪ Learn from Durban experience when updating city master plan to include adaptation ▪ Use experience of Monterrey and Amsterdam in protecting against inland flooding

SLIDE 14



Adaptation and mitigation measures would allow cities to reduce the economic impact of disasters by ~50% to 60%

Percent of expected loss, moderate climate change scenario, 2030

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 14:

Overview of D3 – Adaptation measures

Undertaking adaptation and mitigation measures would allow cities to reduce the economic impact of disasters by ~50% to 60%

The data presented for each city breaks down the projected GDP losses from climate-related disasters into three buckets.

The first bucket, in light orange, is the percentage for which cost-effective measures exist to prevent the damage. This means less will need to be spent on the prevention measures than will be gained from the reduced losses, so the investments will have a positive net present value.

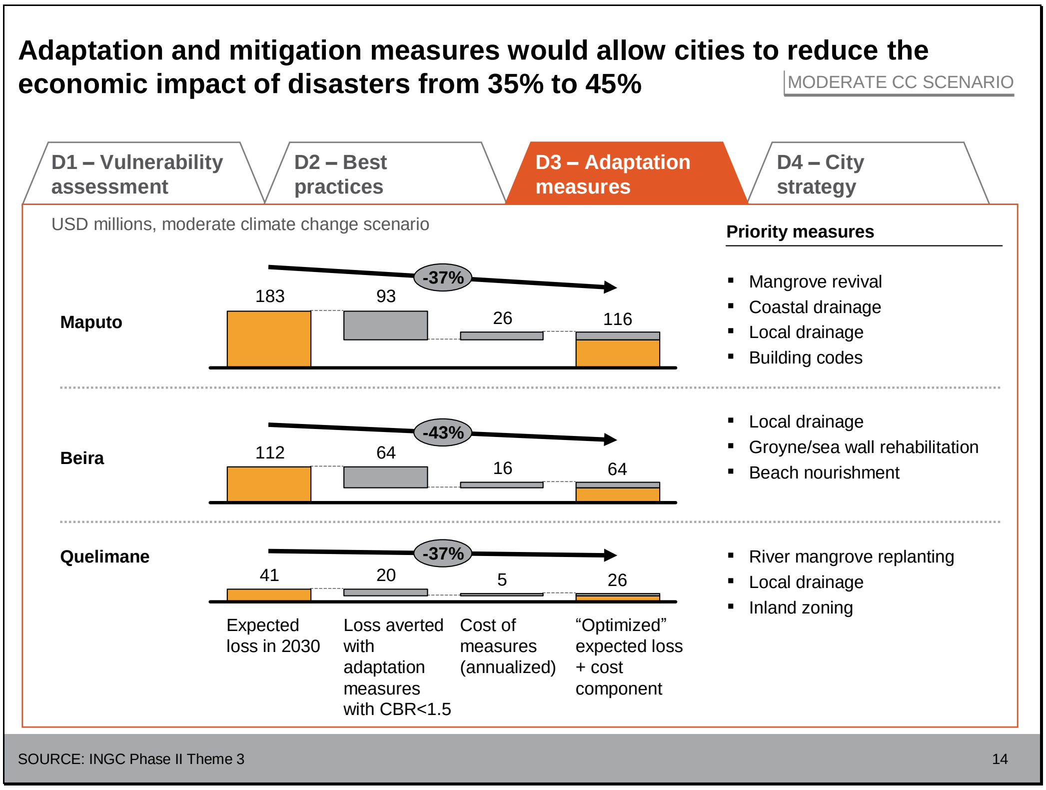
The second category, in grey, shows the percentage of damages which could be prevented, but only by measures that would cost more than the damages prevented, so should not be undertaken.

The third bucket, in red, shows the climate-related damages that cannot be prevented.

Given that all measures in the first bucket are cost-effective and should be undertaken, cities can capture the benefits in orange, which range from ~50 to ~60% of GDP.

An average of similar analyses for other countries is shown at the right for comparison.

SLIDE 15



Adaptation and mitigation measures would allow cities to reduce the economic impact of disasters from 35% to 45%

MODERATE CC SCENARIO

USD millions, moderate climate change scenario

Priority measures

Maputo
- Mangrove revival
- Coastal drainage
- Local drainage
- Building codes

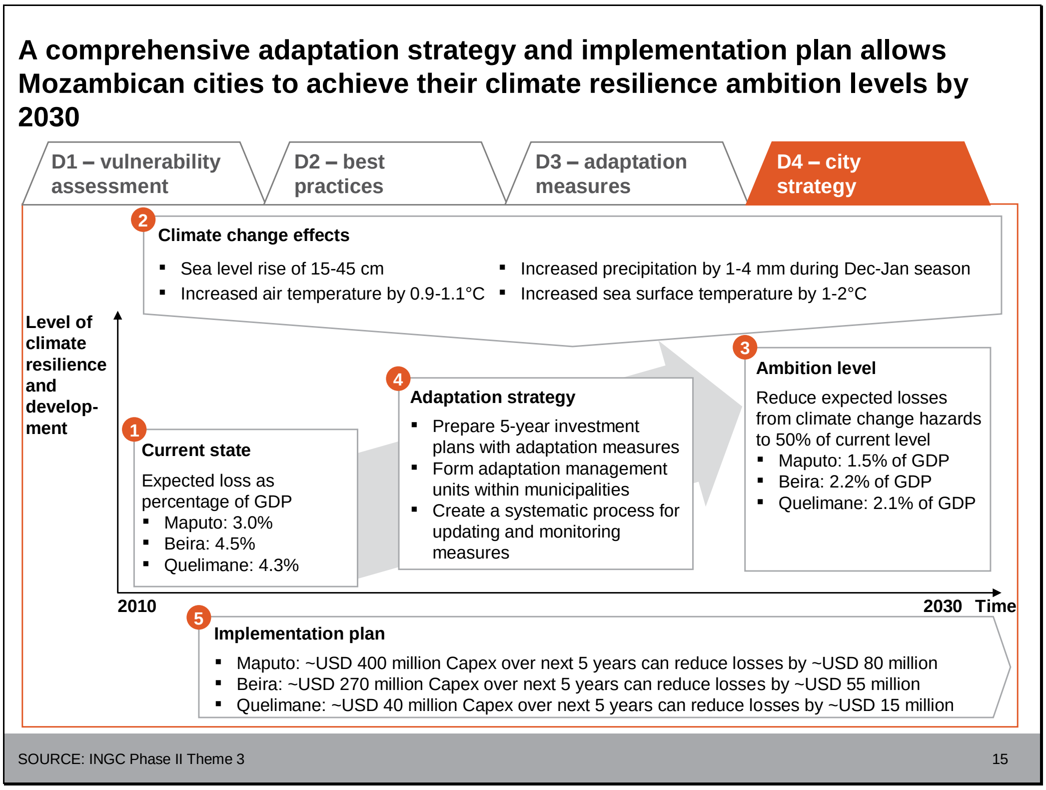
Beira
- Local drainage
- Groyne/sea wall rehabilitation
- Beach nourishment

Quelimane
- River mangrove replanting
- Local drainage
- Inland zoning

SOURCE: INGC Phase II Theme 3

14

SLIDE 16



A comprehensive adaptation strategy and implementation plan allows Mozambican cities to achieve their climate resilience ambition levels by 2030

2 Climate change effects
- Sea level rise of 15-45 cm
- Increased air temperature by 0.9-1.1°C
- Increased precipitation by 1-4 mm during Dec-Jan season
- Increased sea surface temperature by 1-2°C

1 Current state

Expected loss as percentage of GDP
- Maputo: 3.0%
- Beira: 4.5%
- Quelimane: 4.3%

4 Adaptation strategy
- Prepare 5-year investment plans with adaptation measures
- Form adaptation management units within municipalities
- Create a systematic process for updating and monitoring measures

3 Ambition level

Reduce expected losses from climate change hazards to 50% of current level
- Maputo: 1.5% of GDP
- Beira: 2.2% of GDP
- Quelimane: 2.1% of GDP

5 Implementation plan
- Maputo: ~USD 400 million Capex over next 5 years can reduce losses by ~USD 80 million
- Beira: ~USD 270 million Capex over next 5 years can reduce losses by ~USD 55 million
- Quelimane: ~USD 40 million Capex over next 5 years can reduce losses by ~USD 15 million

SOURCE: INGC Phase II Theme 3

15

NOTES FOR SLIDE 16:

Overview of D4 – City strategy

A comprehensive adaptation strategy and implementation plan allows Mozambican cities to achieve their climate resilience ambition levels by 2030

Charts the path to a Mozambican climate adaptation implementation plan through 2030 by following five steps:

First, Mozambican cities are already losing GDP through climate impacts.

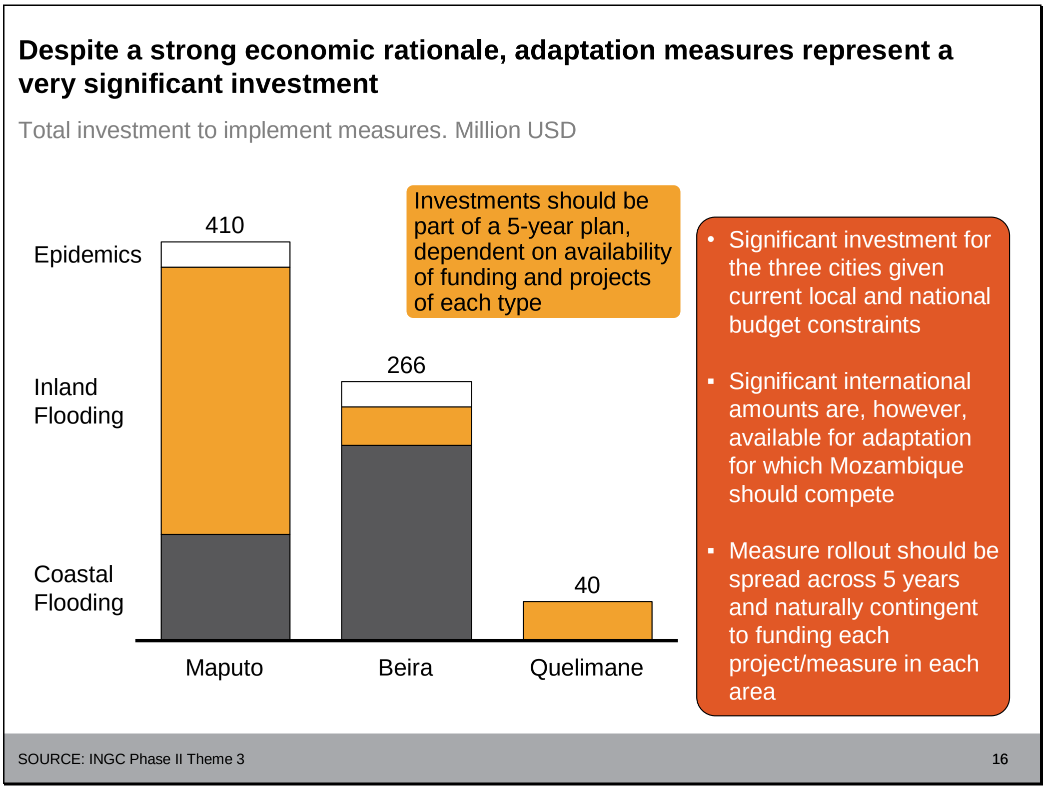
Second, projections on future climate trends show these impacts will become more severe.

Third, Mozambique has set an ambition to curb losses from climate change to 50% of Current level, even given the increasing severity of climate change impacts.

Fourth, to meet these ambitions, Mozambican cities must begin a 5-year investment plan in adaptation measures, and form the necessary organizational bodies and processes to manage and adjust those plans.

Fifth and finally, this adaptation strategy must be translated into a tactical implementation plan, with specific investments tied to projected adaptation benefits through avoided losses.

SLIDE 17



Despite a strong economic rationale, adaptation measures represent a very significant investment

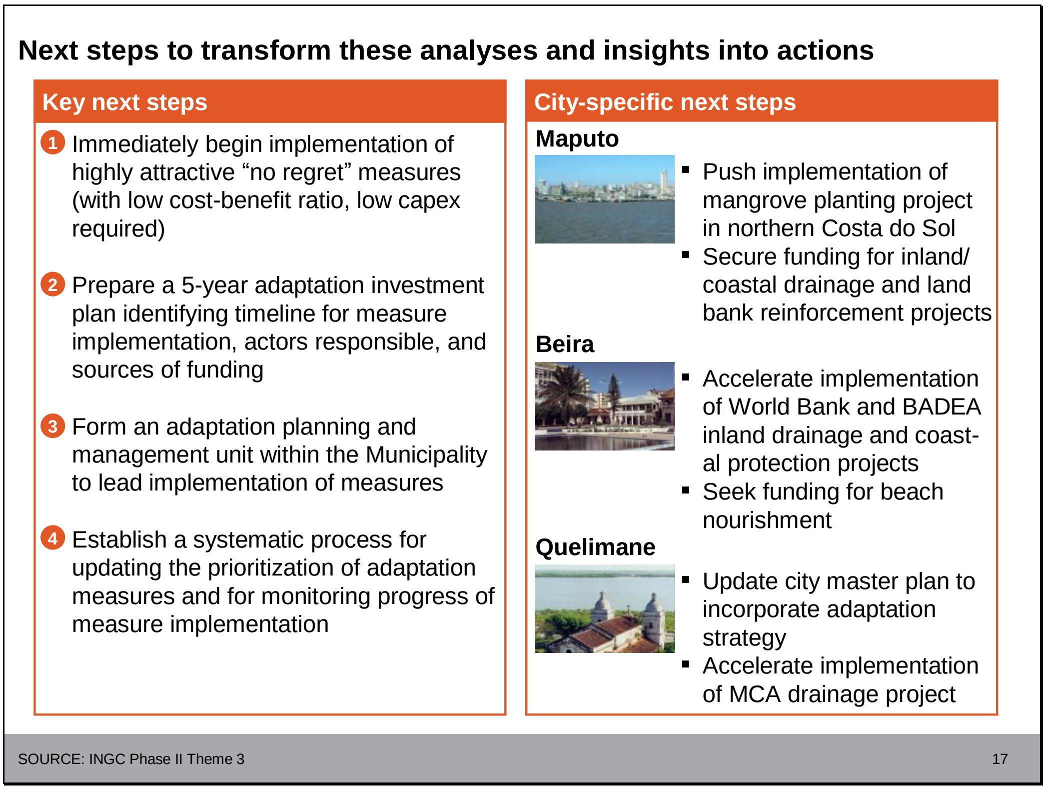
Total investment to implement measures. Million USD

Investments should be part of a 5-year plan, dependent on availability of funding and projects of each type

- Significant investment for the three cities given current local and national budget constraints
- Significant international amounts are, however, available for adaptation for which Mozambique should compete
- Measure rollout should be spread across 5 years and naturally contingent to funding each project/measure in each area

SOURCE: INGC Phase II Theme 3

SLIDE 18



Next steps to transform these analyses and insights into actions

Key next steps

① Immediately begin implementation of highly attractive “no regret” measures (with low cost-benefit ratio, low capex required)

② Prepare a 5-year adaptation investment plan identifying timeline for measure implementation, actors responsible, and sources of funding

③ Form an adaptation planning and management unit within the Municipality to lead implementation of measures

④ Establish a systematic process for updating the prioritization of adaptation measures and for monitoring progress of measure implementation

City-specific next steps

Maputo
- Push implementation of mangrove planting project in northern Costa do Sol
- Secure funding for inland/ coastal drainage and land bank reinforcement projects

Beira
- Accelerate implementation of World Bank and BADEA inland drainage and coastal protection projects
- Seek funding for beach nourishment

Quelimane
- Update city master plan to incorporate adaptation strategy
- Accelerate implementation of MCA drainage project

SOURCE: INGC Phase II Theme 3

SLIDE 19

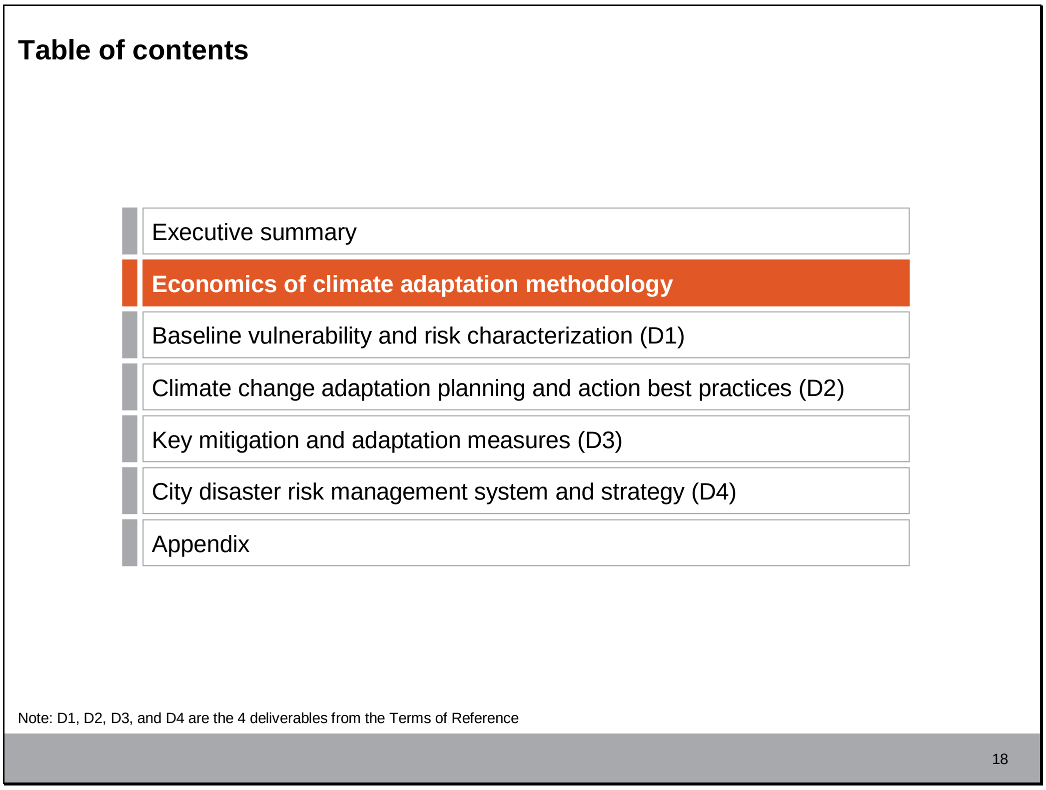
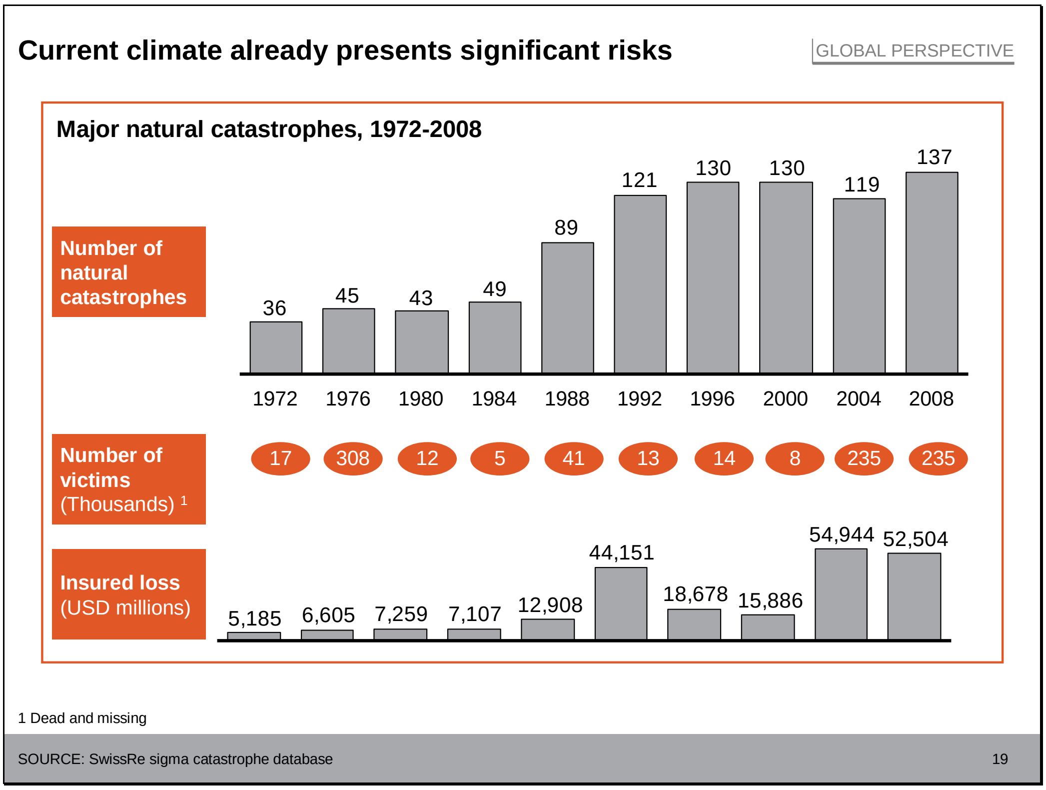


Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 20



Current climate already presents significant risks

GLOBAL PERSPECTIVE

Major natural catastrophes, 1972-2008

1 Dead and missing

SOURCE: SwissRe sigma catastrophe database

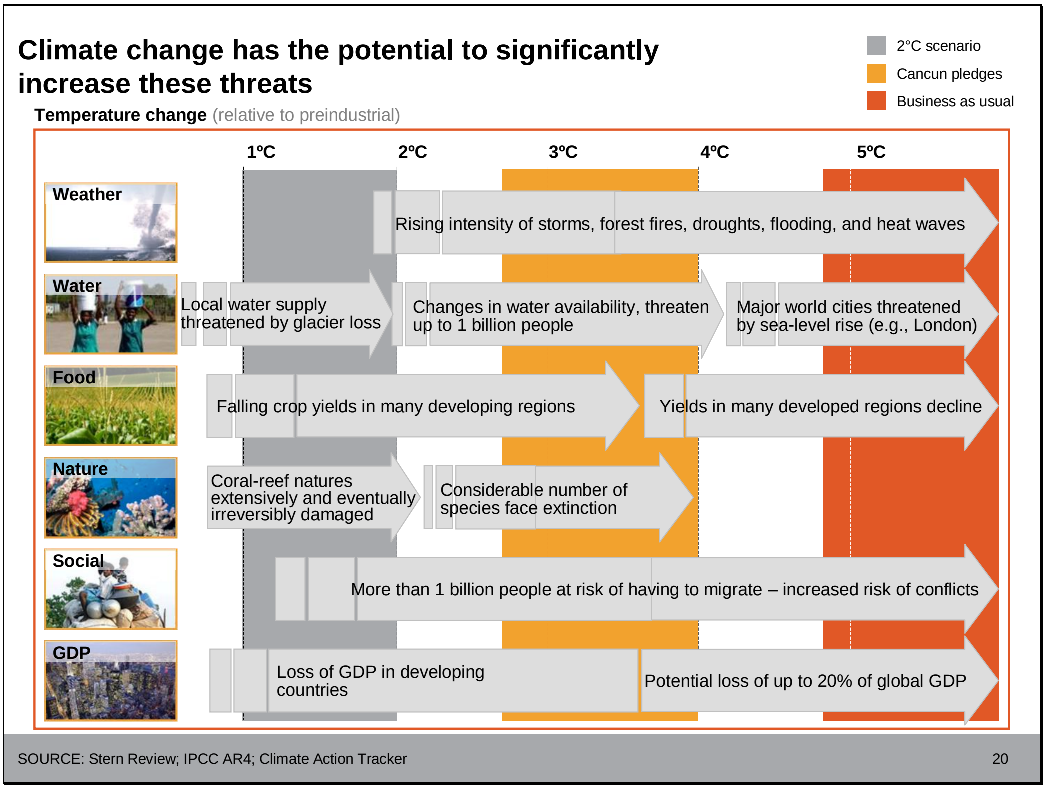
NOTES FOR SLIDE 20:

You can see here that the number of catastrophes has risen sharply. Not all of these are climate-related, but you can see that more people are being hurt.

The financial costs of disasters are also rising.

In a few minutes, we'll talk about why. But looking ahead to even warmer conditions, scientists are contemplating much greater impacts in terms of human health, social costs and economic trouble.

SLIDE 21



Climate change has the potential to significantly increase these threats

▨ 2°C scenario
🟧 Cancun pledges
🟥 Business as usual

Temperature change (relative to preindustrial)

Weather
Rising intensity of storms, forest fires, droughts, flooding, and heat waves

Water
Local water supply threatened by glacier loss
Changes in water availability, threaten up to 1 billion people
Major world cities threatened by sea-level rise (e.g., London)

Food
Falling crop yields in many developing regions
Yields in many developed regions decline

Nature
Coral-reef natures extensively and eventually irreversibly damaged
Considerable number of species face extinction

Social
More than 1 billion people at risk of having to migrate – increased risk of conflicts

GDP
Loss of GDP in developing countries
Potential loss of up to 20% of global GDP

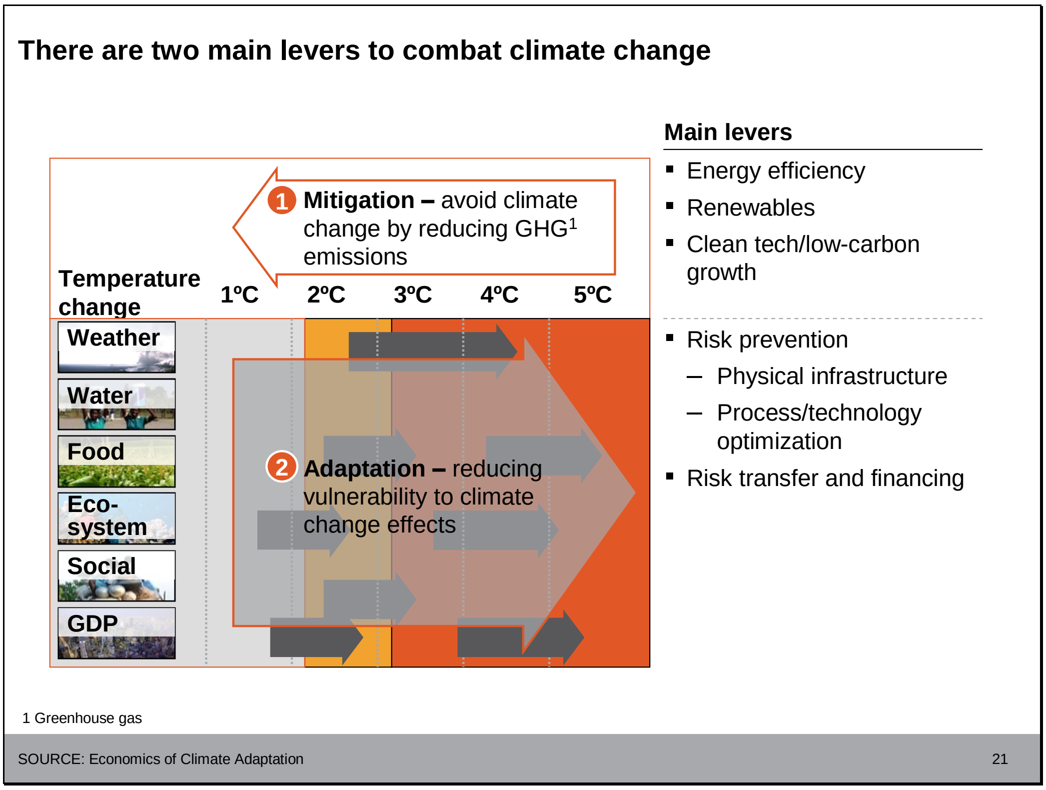
SOURCE: Stern Review; IPCC AR4; Climate Action Tracker

NOTES FOR SLIDE 21:

This chart shows the estimated impact of each degree of increase in the average global temperature. These findings are from the Stern report and have been confirmed by the IPCC.

Because we experience +/-3°C variation in temperatures on a daily basis, it is often difficult for people to imagine the impact of a net 3°C increase in the average global temperature. Do remember though that this is an average global increase – that means that in certain places temperatures will rise more than the average 3 degrees. Even more problematic than the absolute temperature rise is the rate of change. While natures may be able to make long-term adjustments driven by climate shifts, the human species has never before needed to adjust to such rapid changes.

SLIDE 22



There are two main levers to combat climate change

Temperature change

1ºC 2ºC 3ºC 4ºC 5ºC

① **Mitigation –** avoid climate change by reducing GHG[1] emissions

② **Adaptation –** reducing vulnerability to climate change effects

Weather

Water

Food

Eco-system

Social

GDP

Main levers

- Energy efficiency
- Renewables
- Clean tech/low-carbon growth

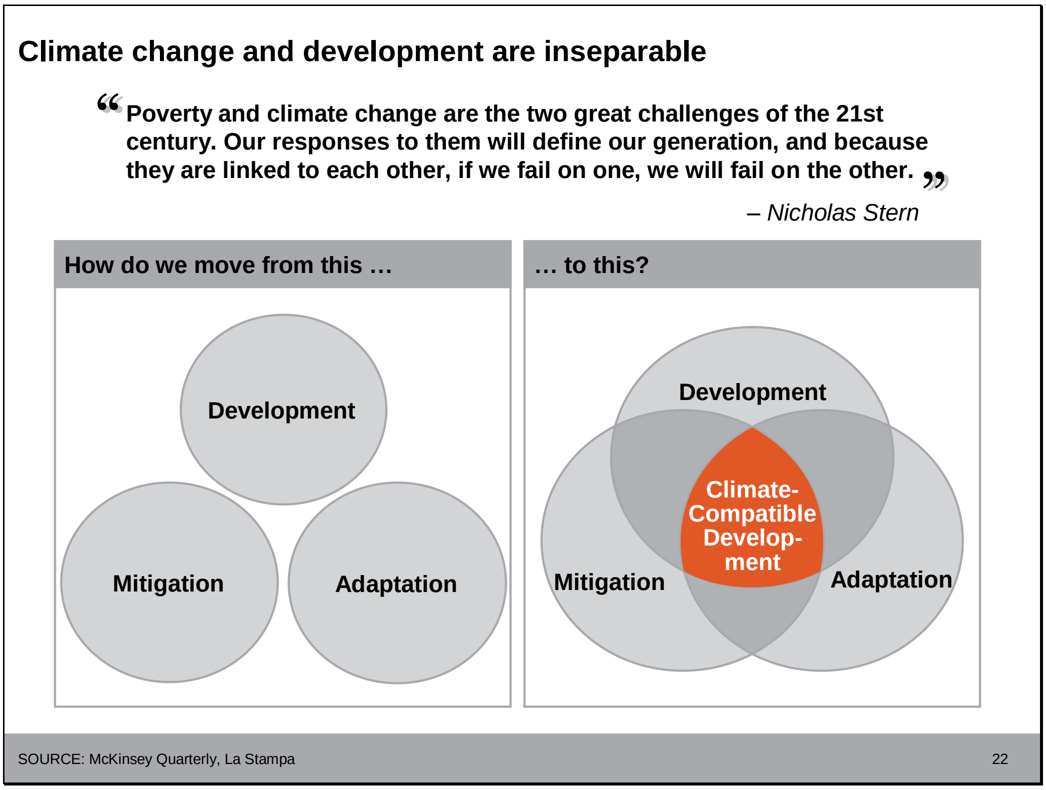
- Risk prevention
  - Physical infrastructure
  - Process/technology optimization
- Risk transfer and financing

1 Greenhouse gas

SOURCE: Economics of Climate Adaptation

21

SLIDE 23



Climate change and development are inseparable

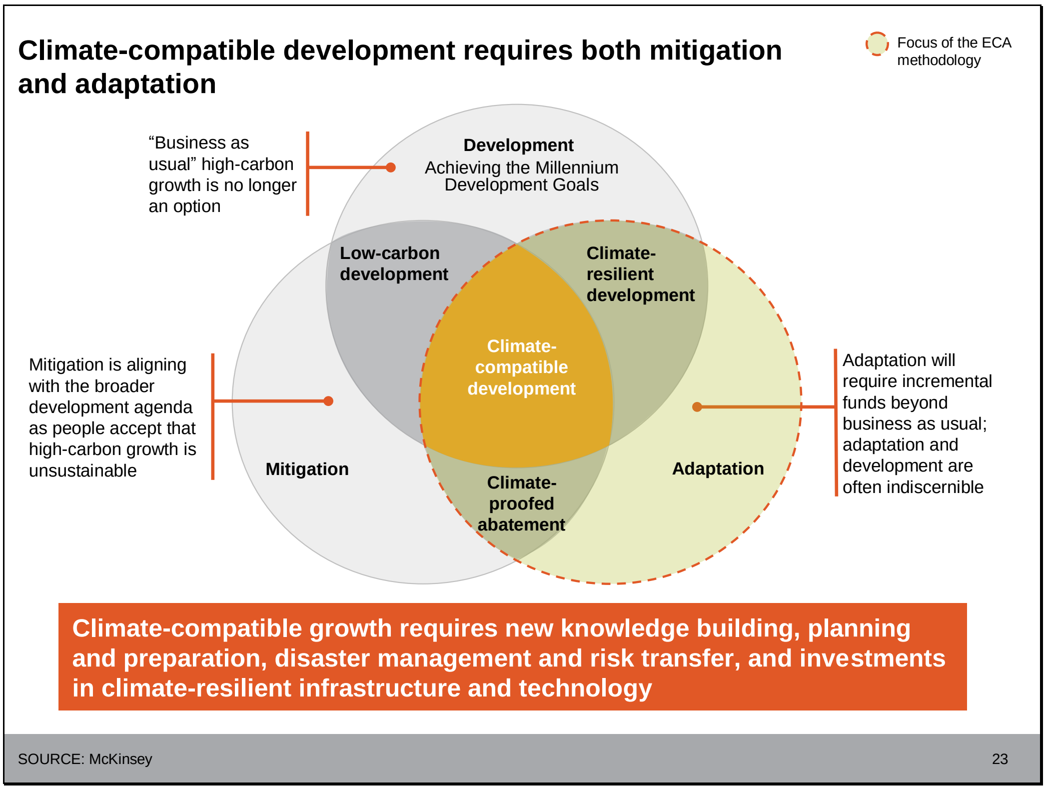
> **“Poverty and climate change are the two great challenges of the 21st century. Our responses to them will define our generation, and because they are linked to each other, if we fail on one, we will fail on the other.”**
>
> *– Nicholas Stern*

How do we move from this …	**… to this?**
Development Mitigation Adaptation	Development Climate-Compatible Develop-ment Mitigation Adaptation

SOURCE: McKinsey Quarterly, La Stampa

22

SLIDE 24



Climate-compatible development requires both mitigation and adaptation

◌ Focus of the ECA methodology

“Business as usual” high-carbon growth is no longer an option

Development
Achieving the Millennium Development Goals

Low-carbon development

Climate-resilient development

Climate-compatible development

Mitigation is aligning with the broader development agenda as people accept that high-carbon growth is unsustainable

Mitigation

Climate-proofed abatement

Adaptation

Adaptation will require incremental funds beyond business as usual; adaptation and development are often indiscernible

Climate-compatible growth requires new knowledge building, planning and preparation, disaster management and risk transfer, and investments in climate-resilient infrastructure and technology

SOURCE: McKinsey

NOTES FOR SLIDE 24:

These overlapping circles represent three different human needs: development, mitigation and adaptation. We can and must meet all of those needs.

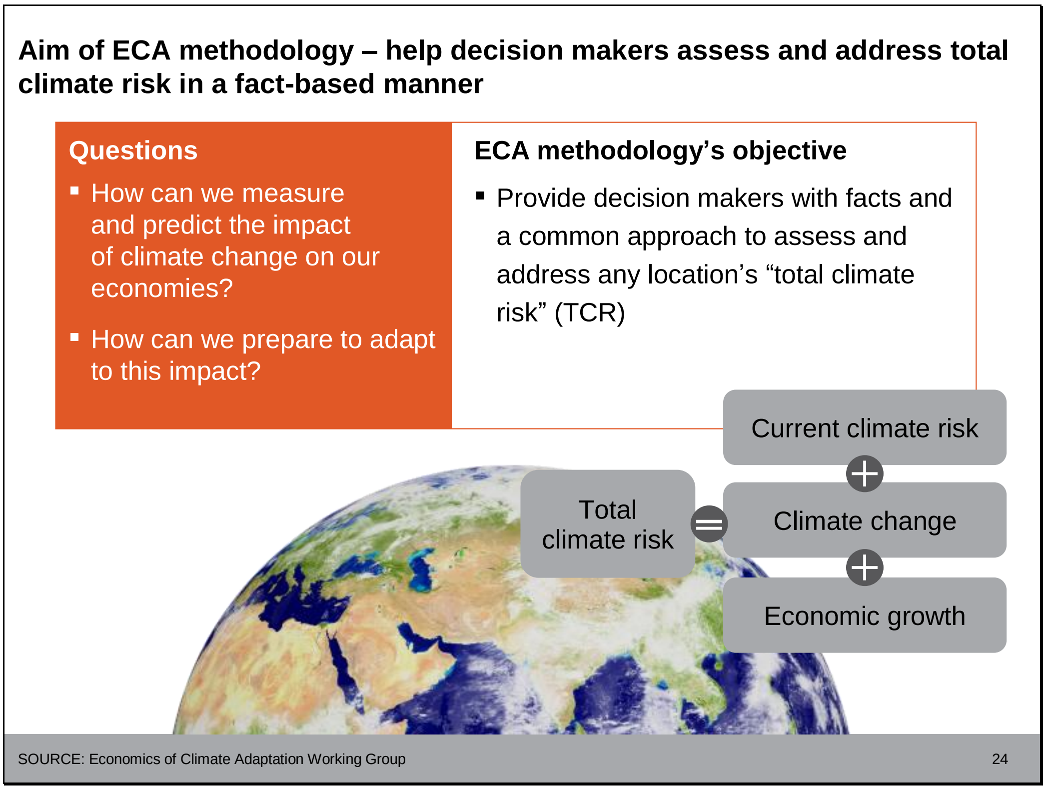
Development has to be low-carbon, as we explain here, and be adapted to resist the impacts of climate change.

Of course, this won’t be easy–even if everyone gets with the program. We can’t do everything because financial and human resources, and time, are limited.

To make wise choices about how to invest scarce resources – to achieve climate-compatible development -- we need more knowledge, planning and preparation. We need better disaster management and insurance. We need new climate-resilient infrastructure and technology.

And that brings us to our second topic…

SLIDE 25



Aim of ECA methodology – help decision makers assess and address total climate risk in a fact-based manner

Questions

- How can we measure and predict the impact of climate change on our economies?
- How can we prepare to adapt to this impact?

ECA methodology's objective

- Provide decision makers with facts and a common approach to assess and address any location's "total climate risk" (TCR)

Total climate risk = Current climate risk + Climate change + Economic growth

SOURCE: Economics of Climate Adaptation Working Group

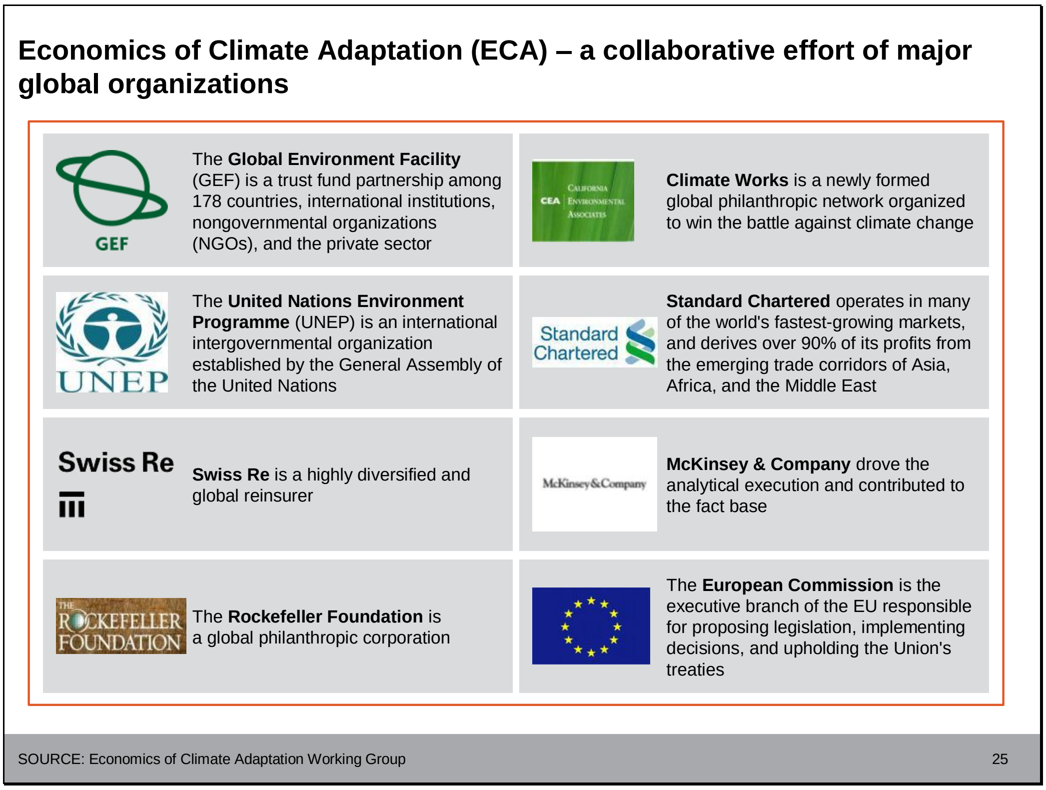
NOTES FOR SLIDE 25:

We need ways to measure and predict the impacts of climate change. And we need to prepare for those changes.

Our work is meant to help you and other leaders use a fact-based approach to answering those questions.

To see if our approach worked, we applied it in eight distinctly different real-world environments…

SLIDE 26

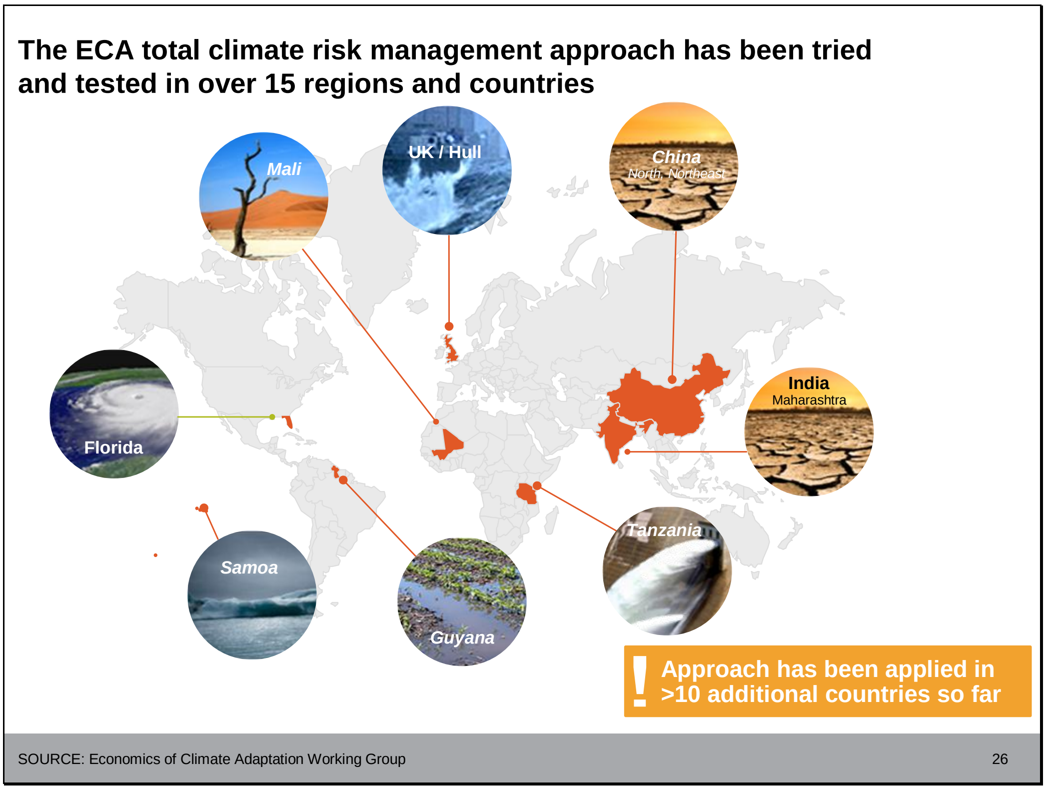


Economics of Climate Adaptation (ECA) – a collaborative effort of major global organizations

The **Global Environment Facility** (GEF) is a trust fund partnership among 178 countries, international institutions, nongovernmental organizations (NGOs), and the private sector	**Climate Works** is a newly formed global philanthropic network organized to win the battle against climate change
The **United Nations Environment Programme** (UNEP) is an international intergovernmental organization established by the General Assembly of the United Nations	**Standard Chartered** operates in many of the world's fastest-growing markets, and derives over 90% of its profits from the emerging trade corridors of Asia, Africa, and the Middle East
Swiss Re is a highly diversified and global reinsurer	**McKinsey & Company** drove the analytical execution and contributed to the fact base
The **Rockefeller Foundation** is a global philanthropic corporation	The **European Commission** is the executive branch of the EU responsible for proposing legislation, implementing decisions, and upholding the Union's treaties

SOURCE: Economics of Climate Adaptation Working Group

SLIDE 27



The ECA total climate risk management approach has been tried and tested in over 15 regions and countries

! Approach has been applied in >10 additional countries so far

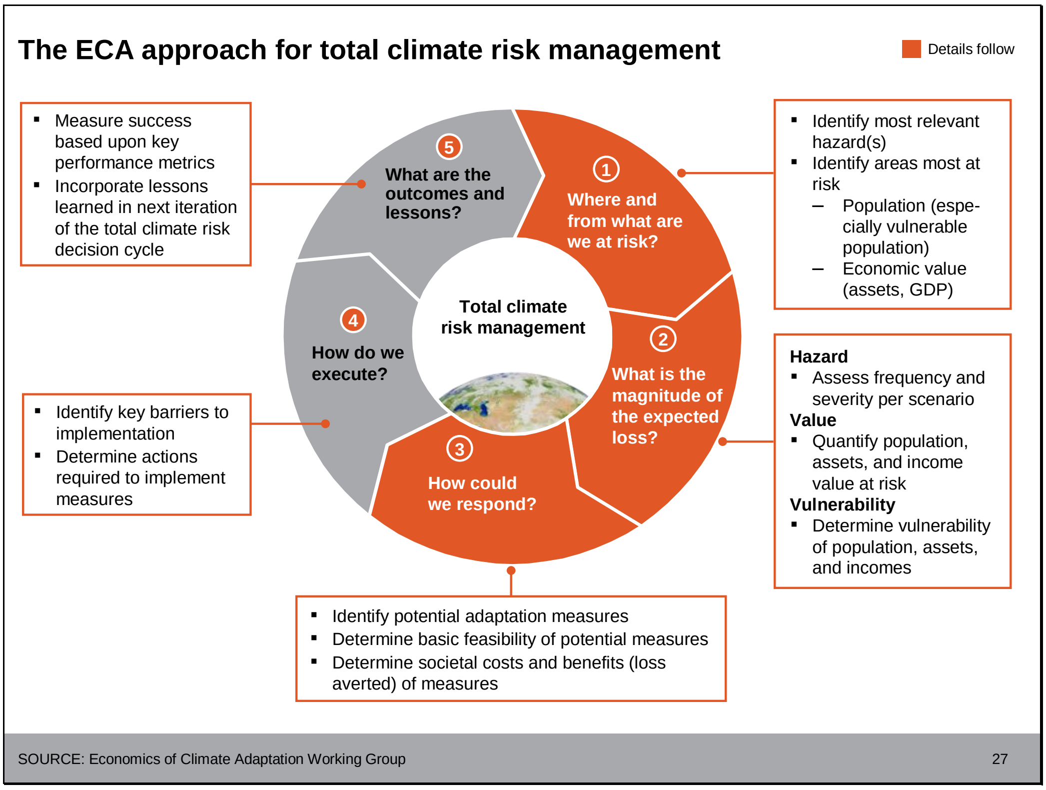
SOURCE: Economics of Climate Adaptation Working Group

NOTES FOR SLIDE 27:

Even with real estate crashing, Florida is still rich. It's also a huge target for hurricanes. Guyana is relatively poor and relies heavily on commodities like sugar and bauxite, whose prices are beyond the country's control.

Despite their many differences, we found that we could use our approach to think about the risks in all of these areas -- and to build a cost-effective portfolio to manage those risks overall, over many years.

SLIDE 28



The ECA approach for total climate risk management

🟧 Details follow

Total climate risk management

① Where and from what are we at risk?
- Identify most relevant hazard(s)
- Identify areas most at risk
  – Population (especially vulnerable population)
  – Economic value (assets, GDP)

② What is the magnitude of the expected loss?

Hazard
- Assess frequency and severity per scenario

Value
- Quantify population, assets, and income value at risk

Vulnerability
- Determine vulnerability of population, assets, and incomes

③ How could we respond?
- Identify potential adaptation measures
- Determine basic feasibility of potential measures
- Determine societal costs and benefits (loss averted) of measures

④ How do we execute?
- Identify key barriers to implementation
- Determine actions required to implement measures

⑤ What are the outcomes and lessons?
- Measure success based upon key performance metrics
- Incorporate lessons learned in next iteration of the total climate risk decision cycle

SOURCE: Economics of Climate Adaptation Working Group

NOTES FOR SLIDE 28:

We begin the process in Step 1 by assessing risks given relevant hazards and what's at stake.

In Step 2, we model scenarios to calculate the total risk. In simple terms, that means considering what's at stake now, what will be at stake as the economy and population grow, and the range of possible climate changes.

In Step 3, we use those scenarios to build a portfolio of possible responses. Drought- or flood-resistant crops might be one worthy investment. Abandoning some land and allowing it to return to wetlands might be another.

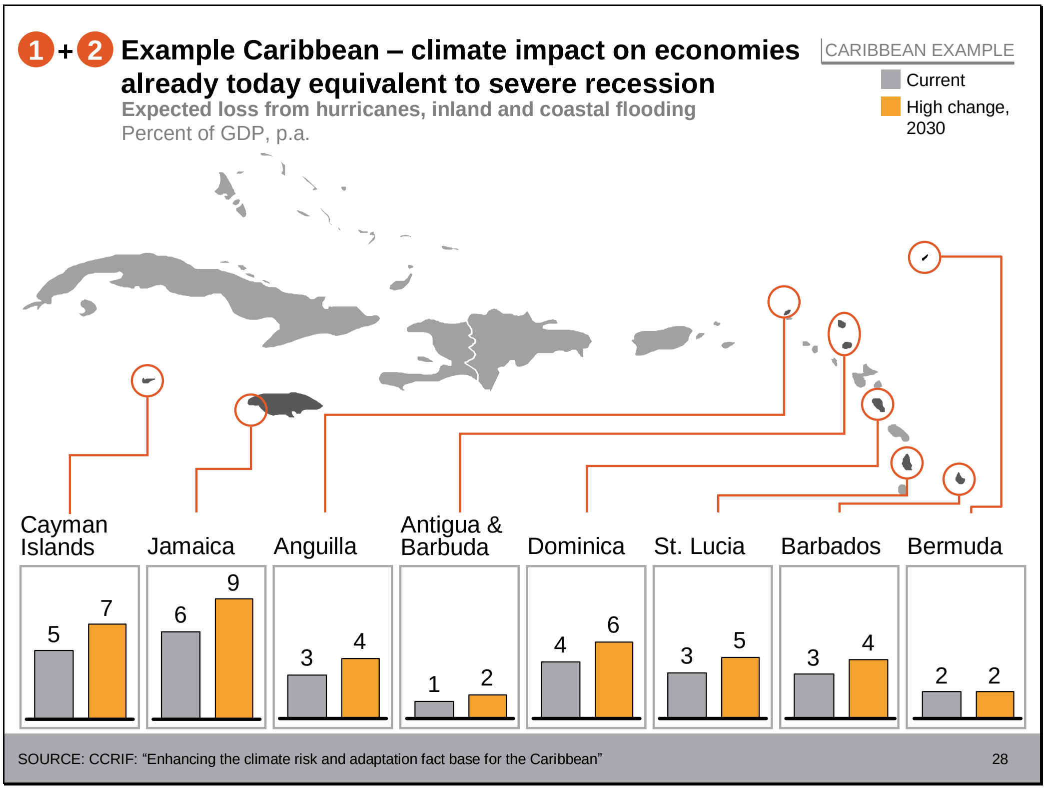
Step 4 in this schematic is putting those actions into place, in the right order, after identifying and overcoming barriers to implementation.

The last step in the cycle is assessing the effects of our approaches, adjusting them based on new information, new technology and fresh predictions.

The climate will keep changing, and this framework accounts for that by looking at total climate risk management as a continuous process.

It is complex, given the many uncertainties about the global climate and the number of moving parts in these equations. But scenario planning allows us to set priorities even without complete or perfect knowledge…

SLIDE 29



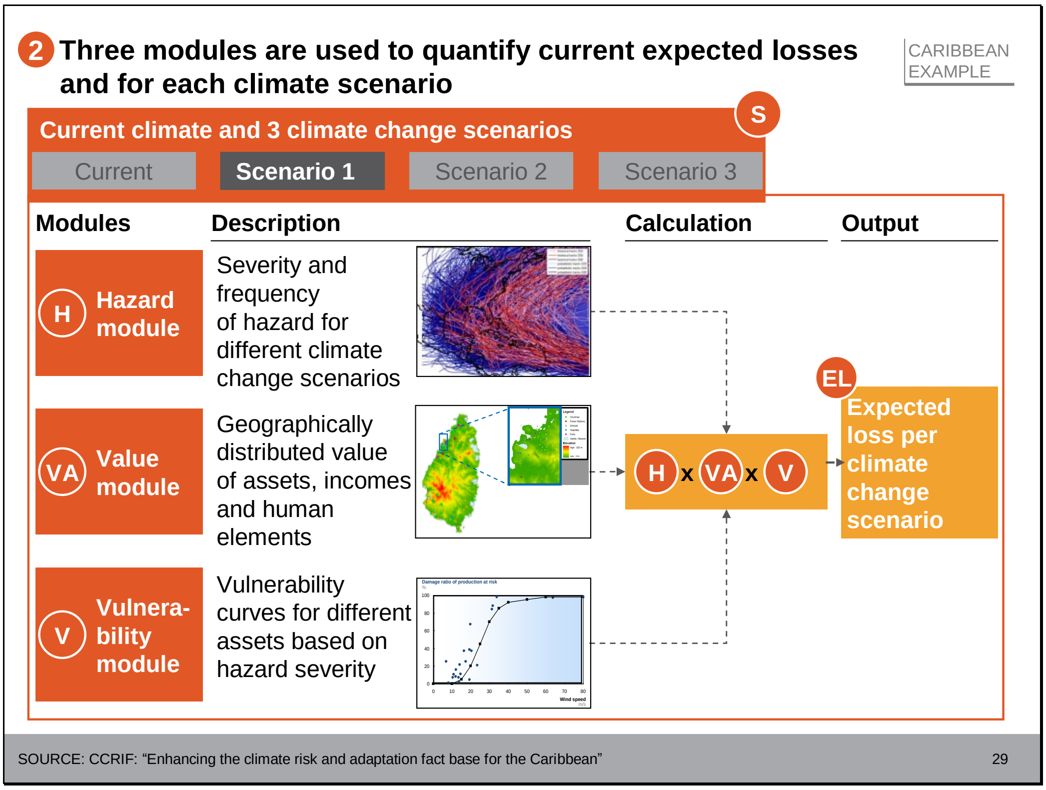
① + ② Example Caribbean – climate impact on economies already today equivalent to severe recession

Expected loss from hurricanes, inland and coastal flooding

Percent of GDP, p.a.

SOURCE: CCRIF: "Enhancing the climate risk and adaptation fact base for the Caribbean"

SLIDE 30



② Three modules are used to quantify current expected losses and for each climate scenario

CARIBBEAN EXAMPLE

Current climate and 3 climate change scenarios (S)

Current | **Scenario 1** | Scenario 2 | Scenario 3

Modules	Description	Calculation	Output
(H) Hazard module	Severity and frequency of hazard for different climate change scenarios	(H) x (VA) x (V)	(EL) **Expected loss per climate change scenario**
(VA) Value module	Geographically distributed value of assets, incomes and human elements		
(V) Vulnera-bility module	Vulnerability curves for different assets based on hazard severity		

SOURCE: CCRIF: “Enhancing the climate risk and adaptation fact base for the Caribbean”

NOTES FOR SLIDE 30:

Considering both economic and human losses, we can use this equation to come up with an expected loss for each scenario.

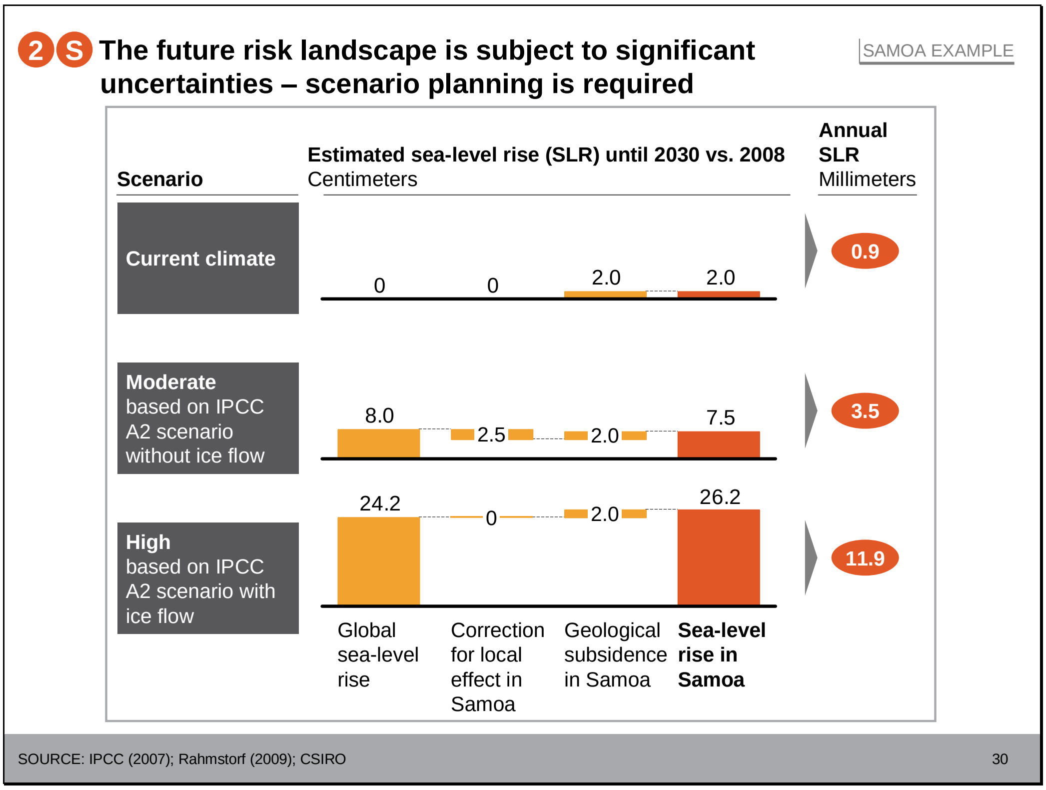
The "hazard module" incorporates the severity and frequency of each risk depending on scenarios.

The "value module" takes into account what is at stake today, and the value of each element as economies and populations grow.

"Vulnerability" refers to how each element at risk may be affected by climate changes.

Together, they give us what we call a "loss exceedence curve"…

SLIDE 31



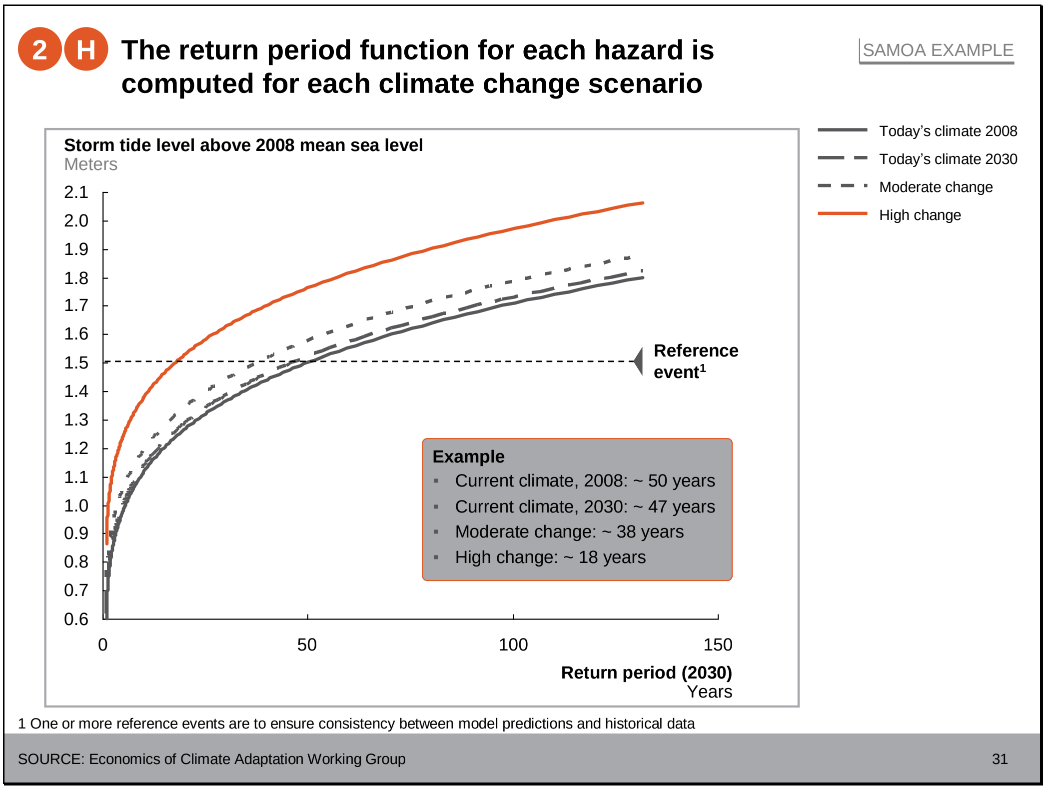
② Ⓢ The future risk landscape is subject to significant uncertainties – scenario planning is required

SAMOA EXAMPLE

Scenario	**Estimated sea-level rise (SLR) until 2030 vs. 2008** Centimeters: Global sea-level rise	Correction for local effect in Samoa	Geological subsidence in Samoa	**Sea-level rise in Samoa**	**Annual SLR** Millimeters
Current climate	0	0	2.0	2.0	0.9
Moderate based on IPCC A2 scenario without ice flow	8.0	2.5	2.0	7.5	3.5
High based on IPCC A2 scenario with ice flow	24.2	0	2.0	26.2	11.9

SOURCE: IPCC (2007); Rahmstorf (2009); CSIRO

SLIDE 32



② Ⓗ The return period function for each hazard is computed for each climate change scenario

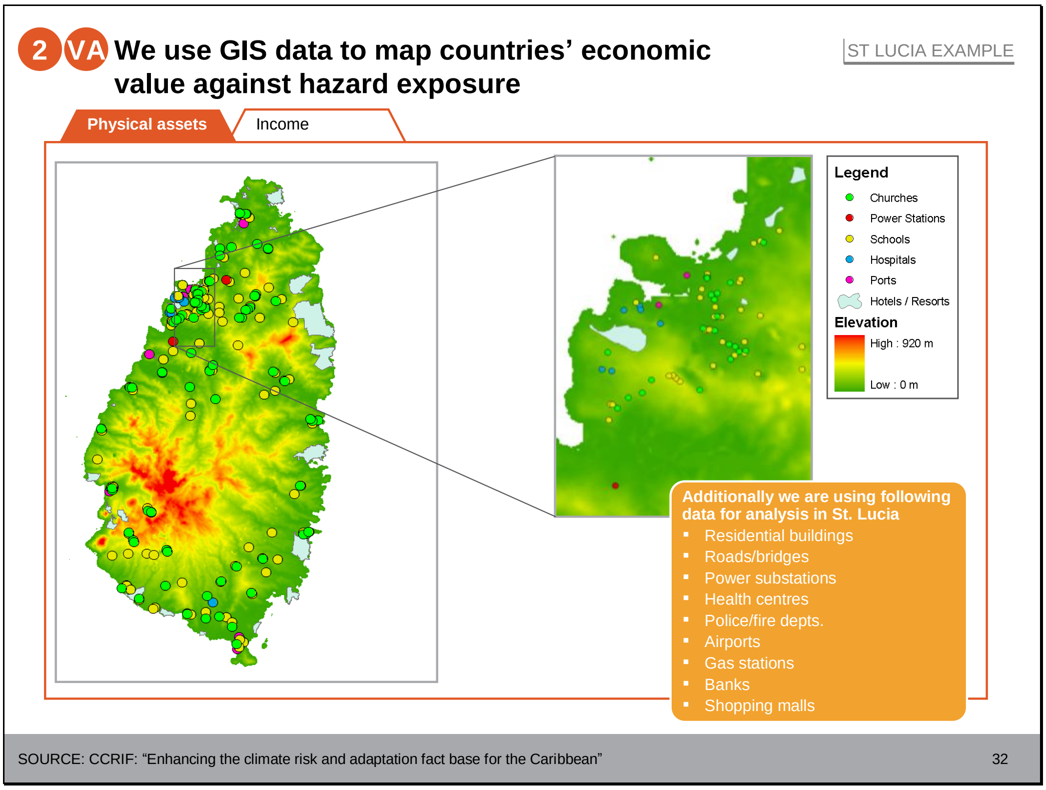
SAMOA EXAMPLE

Example
- Current climate, 2008: ~ 50 years
- Current climate, 2030: ~ 47 years
- Moderate change: ~ 38 years
- High change: ~ 18 years

1 One or more reference events are to ensure consistency between model predictions and historical data

SOURCE: Economics of Climate Adaptation Working Group

SLIDE 33



2 VA We use GIS data to map countries' economic value against hazard exposure

ST LUCIA EXAMPLE

Physical assets | Income

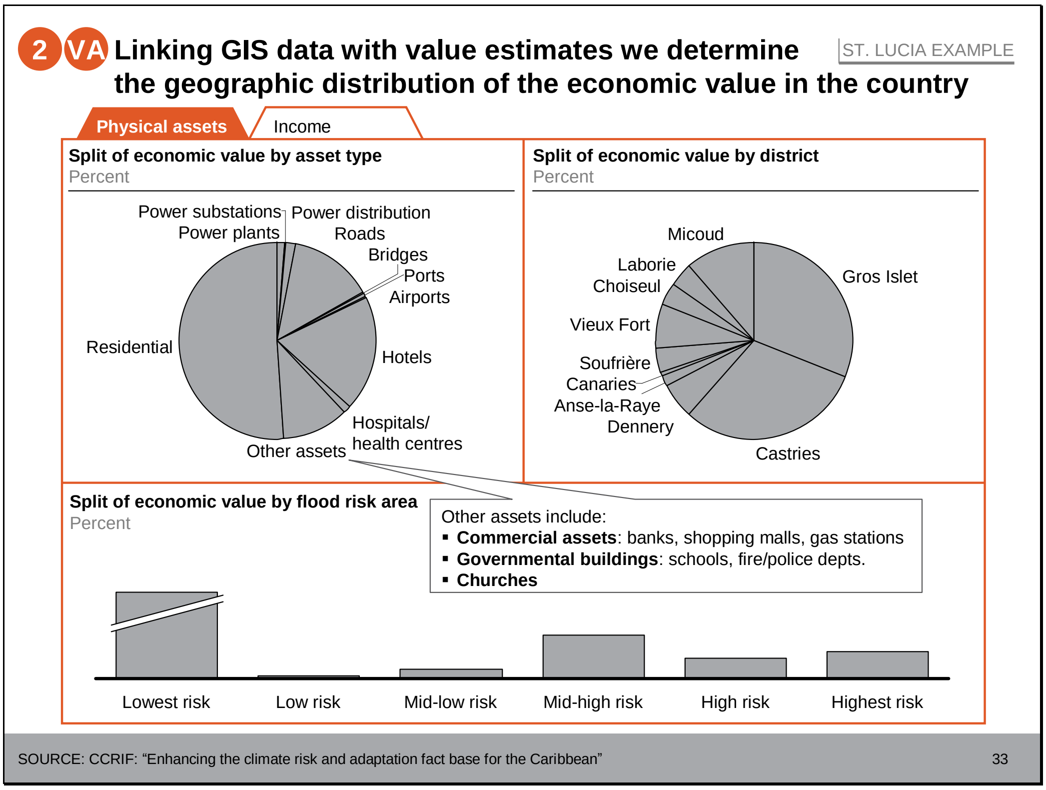
Additionally we are using following data for analysis in St. Lucia

- Residential buildings
- Roads/bridges
- Power substations
- Health centres
- Police/fire depts.
- Airports
- Gas stations
- Banks
- Shopping malls

SOURCE: CCRIF: "Enhancing the climate risk and adaptation fact base for the Caribbean"

32

SLIDE 34



2 VA Linking GIS data with value estimates we determine the geographic distribution of the economic value in the country

ST. LUCIA EXAMPLE

Physical assets | Income

Split of economic value by asset type
Percent

Split of economic value by district
Percent

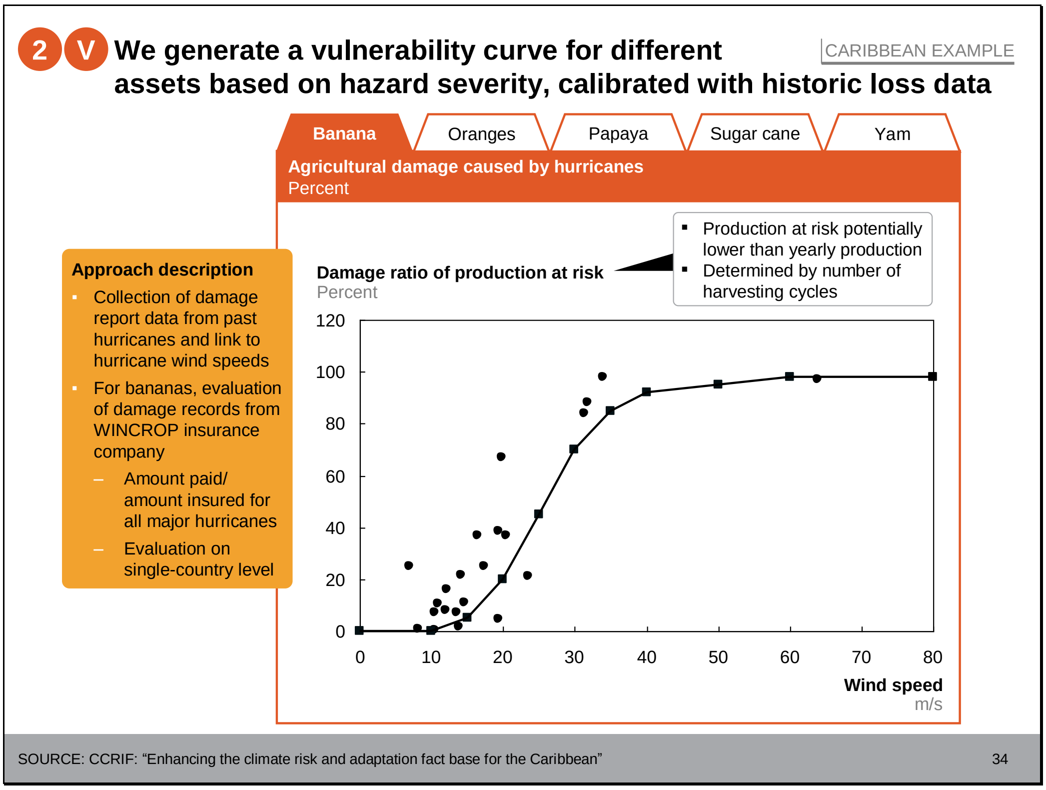
Split of economic value by flood risk area
Percent

Other assets include:
- **Commercial assets**: banks, shopping malls, gas stations
- **Governmental buildings**: schools, fire/police depts.
- **Churches**

SOURCE: CCRIF: "Enhancing the climate risk and adaptation fact base for the Caribbean"

33

SLIDE 35



2 V **We generate a vulnerability curve for different assets based on hazard severity, calibrated with historic loss data**

CARIBBEAN EXAMPLE

Approach description

- Collection of damage report data from past hurricanes and link to hurricane wind speeds
- For bananas, evaluation of damage records from WINCROP insurance company
  - – Amount paid/ amount insured for all major hurricanes
  - – Evaluation on single-country level

- Production at risk potentially lower than yearly production
- Determined by number of harvesting cycles

SOURCE: CCRIF: “Enhancing the climate risk and adaptation fact base for the Caribbean”

NOTES FOR SLIDE 35:

Economics of Climate Change Approach for Total Climate Risk Management – Magnitude of Expected Loss – Vulnerability Module

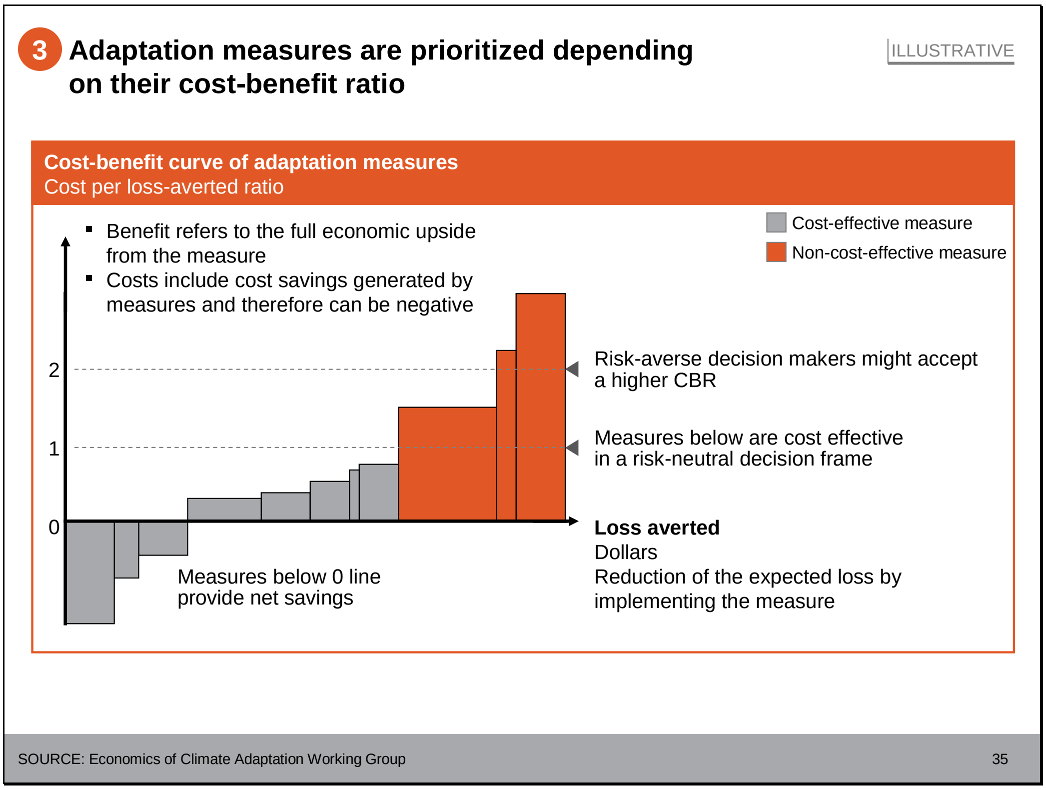
This example of a Caribbean country shows a vulnerability curve generated for an asset, bananas, based on hazard (wind) severity, calibrated with historic loss data.

To give an example of the kinds of vulnerability analyses underaken through the ECA tool, the percentage of the banana crop, a valuable asset, that will be damaged is charted at different wind speeds.

The x axis is a number of different wind speeds in m/s. The y axis is the proportion of the production of bananas at risk of wind damage at any one time that will be damaged by a particular wind speed.

This kind of analysis, when plotted with the projected frequency of high wind speed events under different climate scenarios, is used to build a bottom up picture of asset vulnerability to climate change.

SLIDE 36



③ Adaptation measures are prioritized depending on their cost-benefit ratio

ILLUSTRATIVE

Cost-benefit curve of adaptation measures
Cost per loss-averted ratio

- Benefit refers to the full economic upside from the measure
- Costs include cost savings generated by measures and therefore can be negative

▨ Cost-effective measure
🟥 Non-cost-effective measure

Risk-averse decision makers might accept a higher CBR

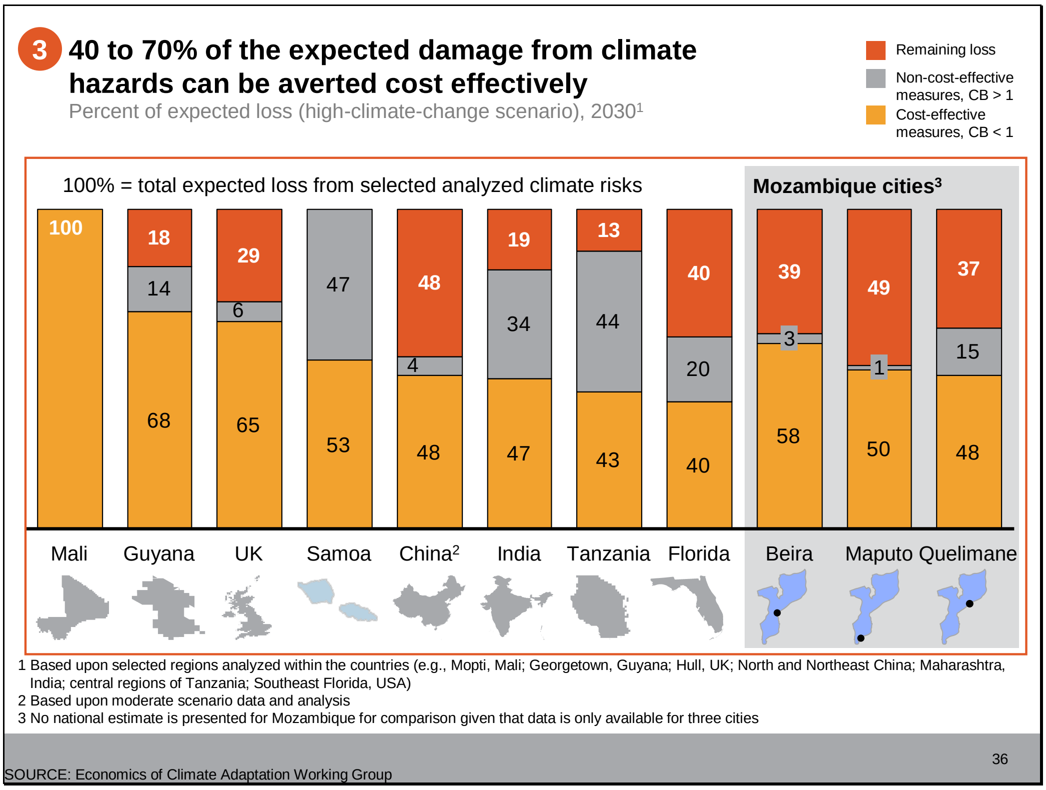
Measures below are cost effective in a risk-neutral decision frame

Loss averted
Dollars
Reduction of the expected loss by implementing the measure

Measures below 0 line provide net savings

SOURCE: Economics of Climate Adaptation Working Group

SLIDE 37



③ 40 to 70% of the expected damage from climate hazards can be averted cost effectively

Percent of expected loss (high-climate-change scenario), 2030[1]

🟥 Remaining loss
▨ Non-cost-effective measures, CB > 1
🟧 Cost-effective measures, CB < 1

100% = total expected loss from selected analyzed climate risks

Mozambique cities[3]

1 Based upon selected regions analyzed within the countries (e.g., Mopti, Mali; Georgetown, Guyana; Hull, UK; North and Northeast China; Maharashtra, India; central regions of Tanzania; Southeast Florida, USA)
2 Based upon moderate scenario data and analysis
3 No national estimate is presented for Mozambique for comparison given that data is only available for three cities

SOURCE: Economics of Climate Adaptation Working Group

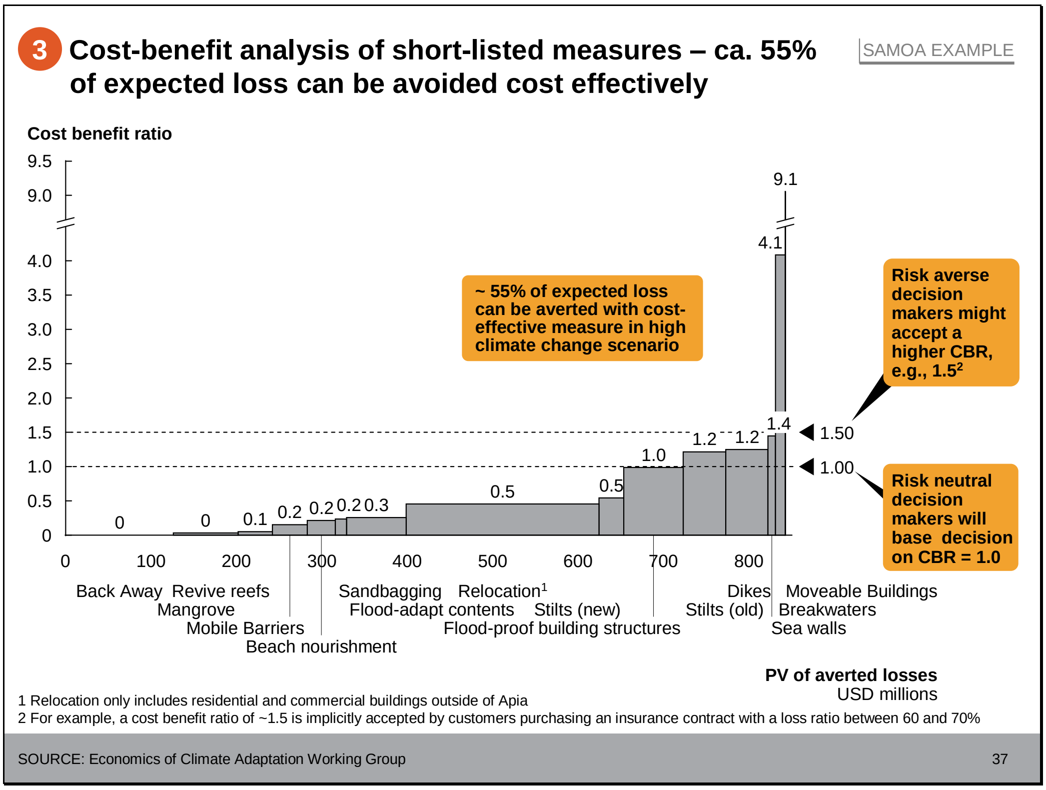
NOTES FOR SLIDE 37:

On the left of this slide, you see that multiple predictions exist for rainfall in Tanzania 20 years from now. Each prediction has been made by groups of credible scientists, and we can see that they vary widely.

But we can group the predictions into the three scenarios on the right.

Then we use them to calculate expected losses…

SLIDE 38



3 **Cost-benefit analysis of short-listed measures – ca. 55% of expected loss can be avoided cost effectively**

SAMOA EXAMPLE

~ 55% of expected loss can be averted with cost-effective measure in high climate change scenario

Risk averse decision makers might accept a higher CBR, e.g., 1.5[2]

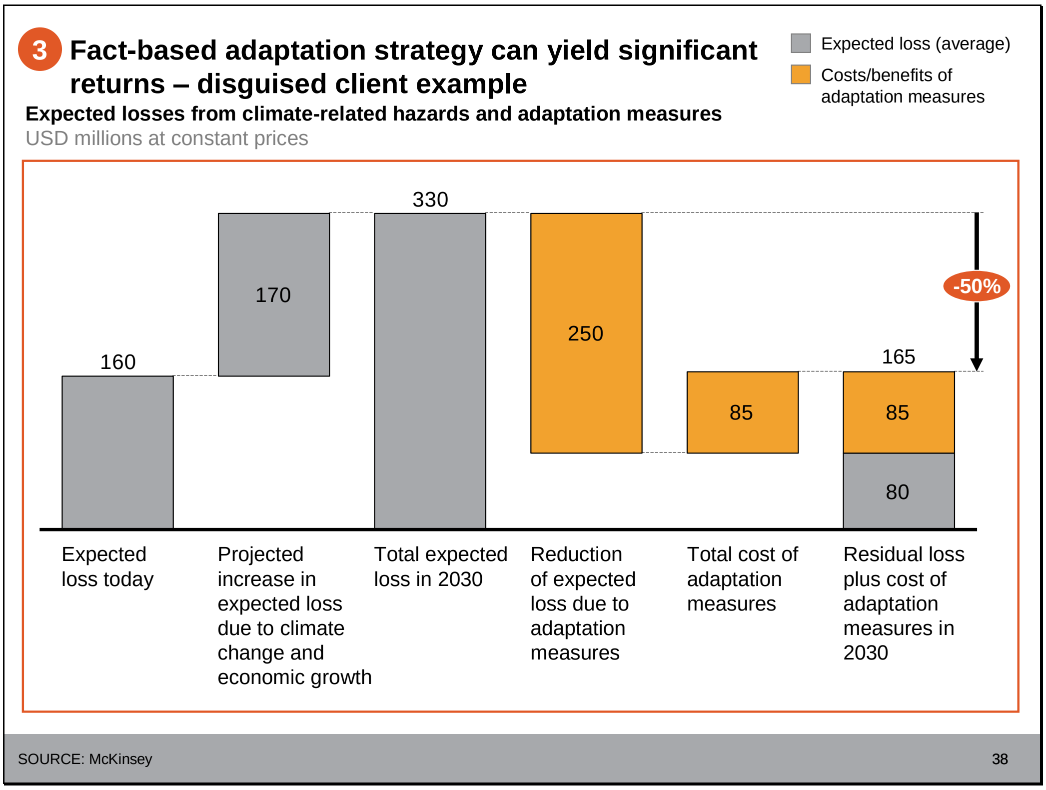
Risk neutral decision makers will base decision on CBR = 1.0

1 Relocation only includes residential and commercial buildings outside of Apia
2 For example, a cost benefit ratio of ~1.5 is implicitly accepted by customers purchasing an insurance contract with a loss ratio between 60 and 70%

SOURCE: Economics of Climate Adaptation Working Group

37

SLIDE 39



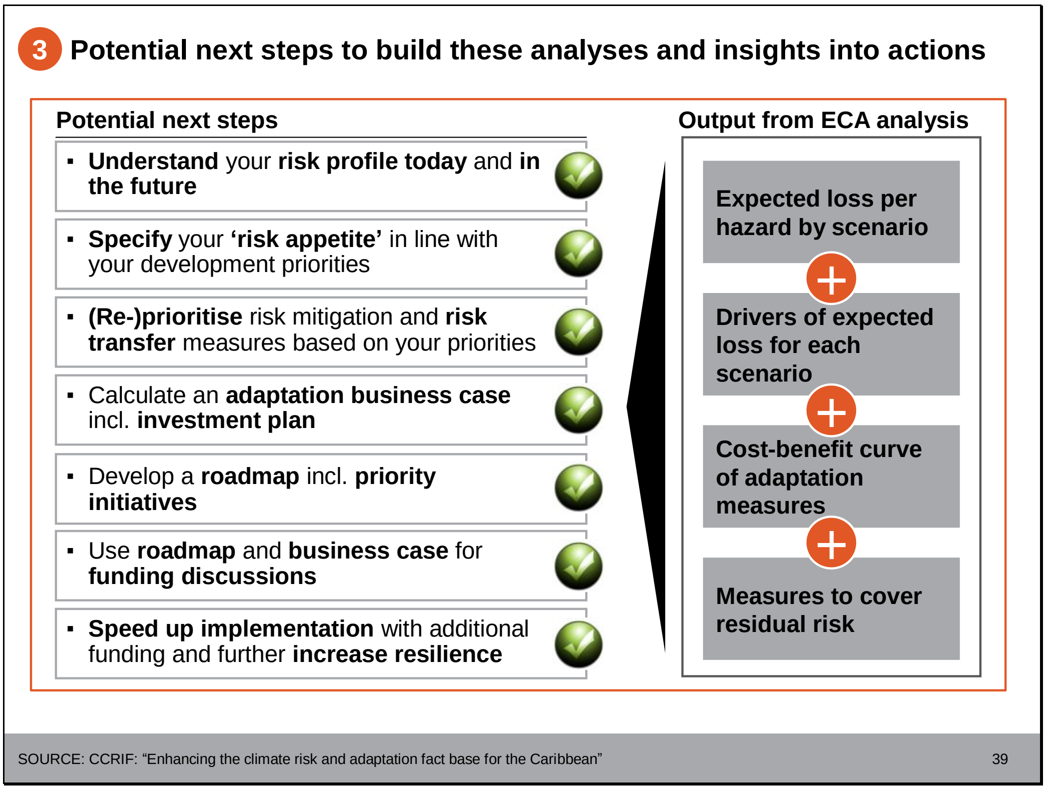
3 Fact-based adaptation strategy can yield significant returns – disguised client example

Expected losses from climate-related hazards and adaptation measures

USD millions at constant prices

SOURCE: McKinsey

SLIDE 40



3 Potential next steps to build these analyses and insights into actions

Potential next steps

- **Understand** your **risk profile today** and **in the future**
- **Specify** your **'risk appetite'** in line with your development priorities
- **(Re-)prioritise** risk mitigation and **risk transfer** measures based on your priorities
- Calculate an **adaptation business case** incl. **investment plan**
- Develop a **roadmap** incl. **priority initiatives**
- Use **roadmap** and **business case** for **funding discussions**
- **Speed up implementation** with additional funding and further **increase resilience**

Output from ECA analysis

Expected loss per hazard by scenario

\+

Drivers of expected loss for each scenario

\+

Cost-benefit curve of adaptation measures

\+

Measures to cover residual risk

SOURCE: CCRIF: "Enhancing the climate risk and adaptation fact base for the Caribbean"

SLIDE 41

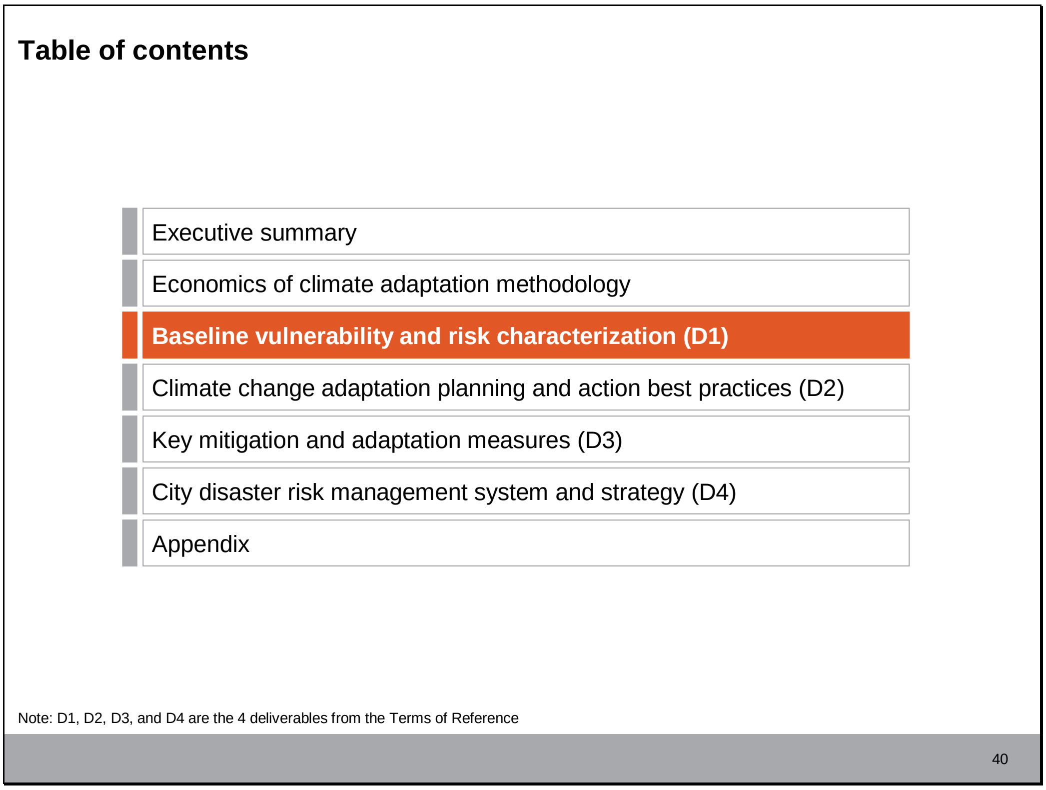
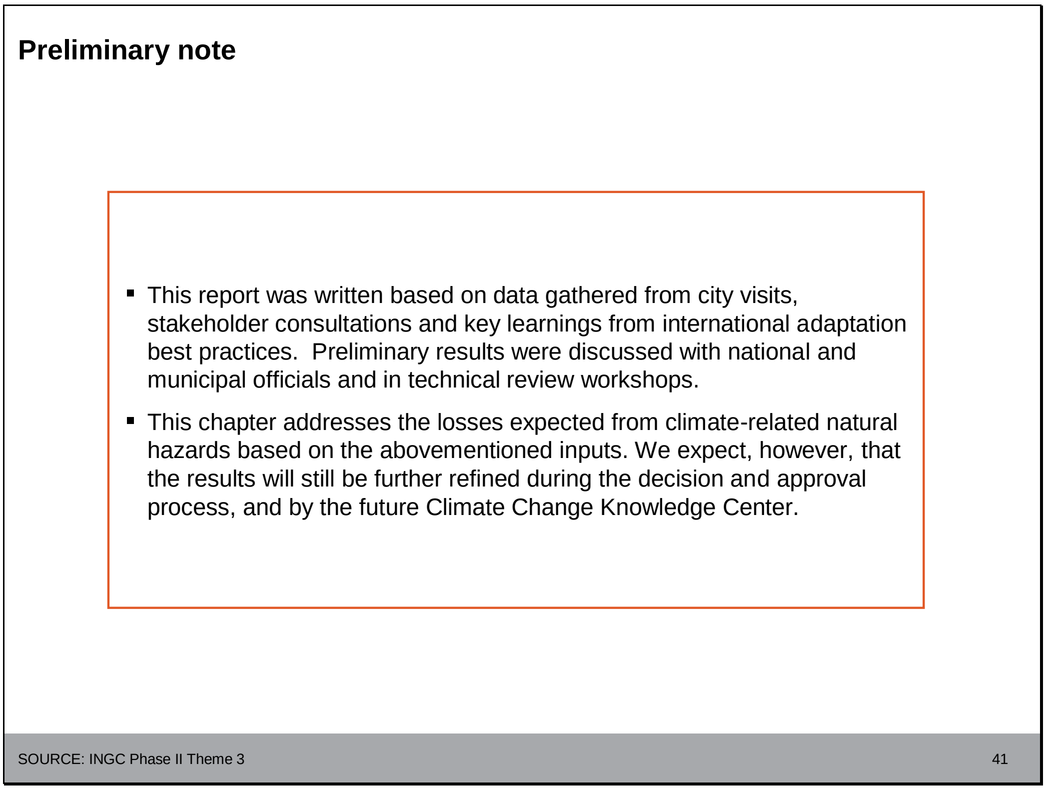


Table of contents

- Executive summary
- Economics of climate adaptation methodology
- **Baseline vulnerability and risk characterization (D1)**
- Climate change adaptation planning and action best practices (D2)
- Key mitigation and adaptation measures (D3)
- City disaster risk management system and strategy (D4)
- Appendix

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 42

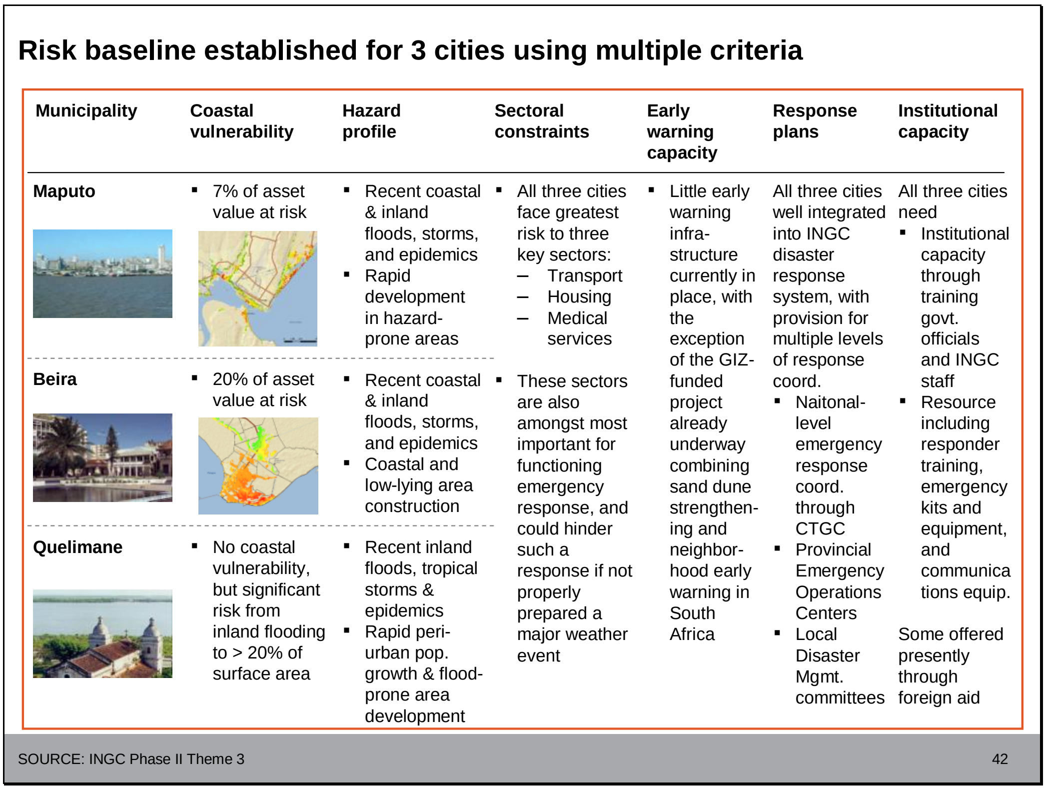


Preliminary note

- This report was written based on data gathered from city visits, stakeholder consultations and key learnings from international adaptation best practices. Preliminary results were discussed with national and municipal officials and in technical review workshops.
- This chapter addresses the losses expected from climate-related natural hazards based on the abovementioned inputs. We expect, however, that the results will still be further refined during the decision and approval process, and by the future Climate Change Knowledge Center.

SOURCE: INGC Phase II Theme 3

SLIDE 43

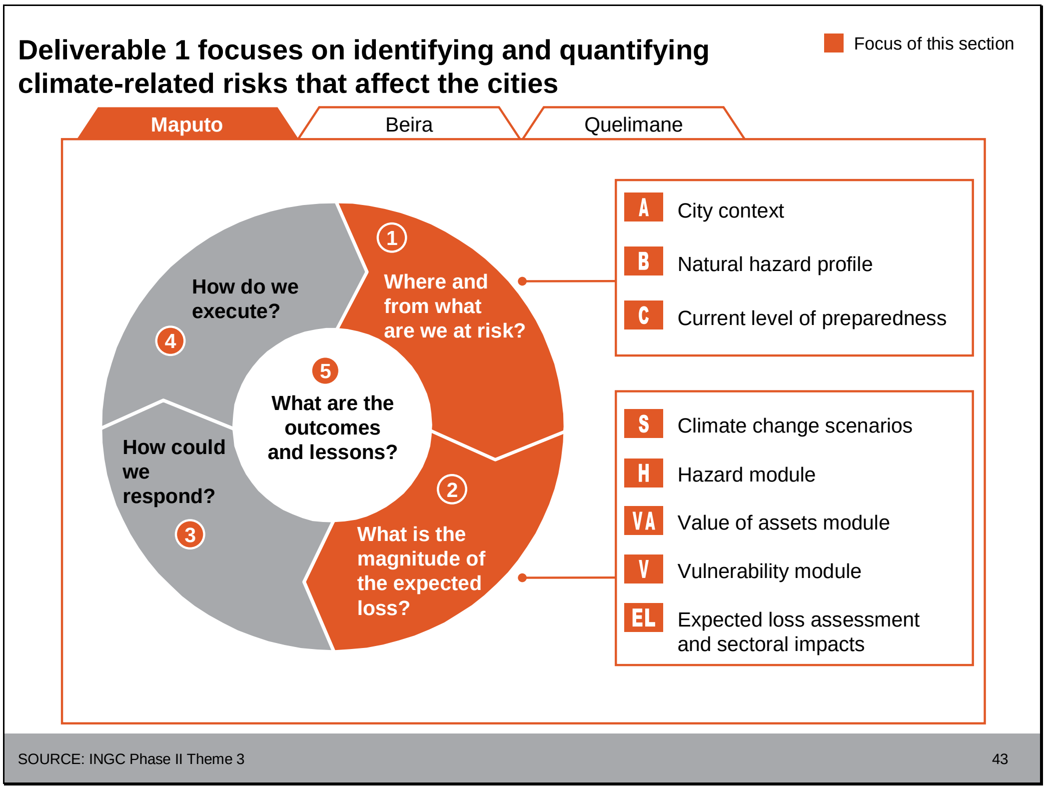


Risk baseline established for 3 cities using multiple criteria

Municipality	Coastal vulnerability	Hazard profile	Sectoral constraints	Early warning capacity	Response plans	Institutional capacity
Maputo	▪ 7% of asset value at risk	▪ Recent coastal & inland floods, storms, and epidemics ▪ Rapid development in hazard-prone areas	▪ All three cities face greatest risk to three key sectors: – Transport – Housing – Medical services	▪ Little early warning infra-structure currently in place, with the exception of the GIZ-funded project already underway combining sand dune strengthen-ing and neighbor-hood early warning in South Africa	All three cities well integrated into INGC disaster response system, with provision for multiple levels of response coord. ▪ Naitonal-level emergency response coord. through CTGC ▪ Provincial Emergency Operations Centers ▪ Local Disaster Mgmt. committees	All three cities need ▪ Institutional capacity through training govt. officials and INGC staff ▪ Resource including responder training, emergency kits and equipment, and communica tions equip. Some offered presently through foreign aid
Beira	▪ 20% of asset value at risk	▪ Recent coastal & inland floods, storms, and epidemics ▪ Coastal and low-lying area construction	▪ These sectors are also amongst most important for functioning emergency response, and could hinder such a response if not properly prepared a major weather event			
Quelimane	▪ No coastal vulnerability, but significant risk from inland flooding to > 20% of surface area	▪ Recent inland floods, tropical storms & epidemics ▪ Rapid peri-urban pop. growth & flood-prone area development				

SOURCE: INGC Phase II Theme 3

SLIDE 44



Deliverable 1 focuses on identifying and quantifying climate-related risks that affect the cities

🟧 Focus of this section

① Where and from what are we at risk?

② What is the magnitude of the expected loss?

③ How could we respond?

④ How do we execute?

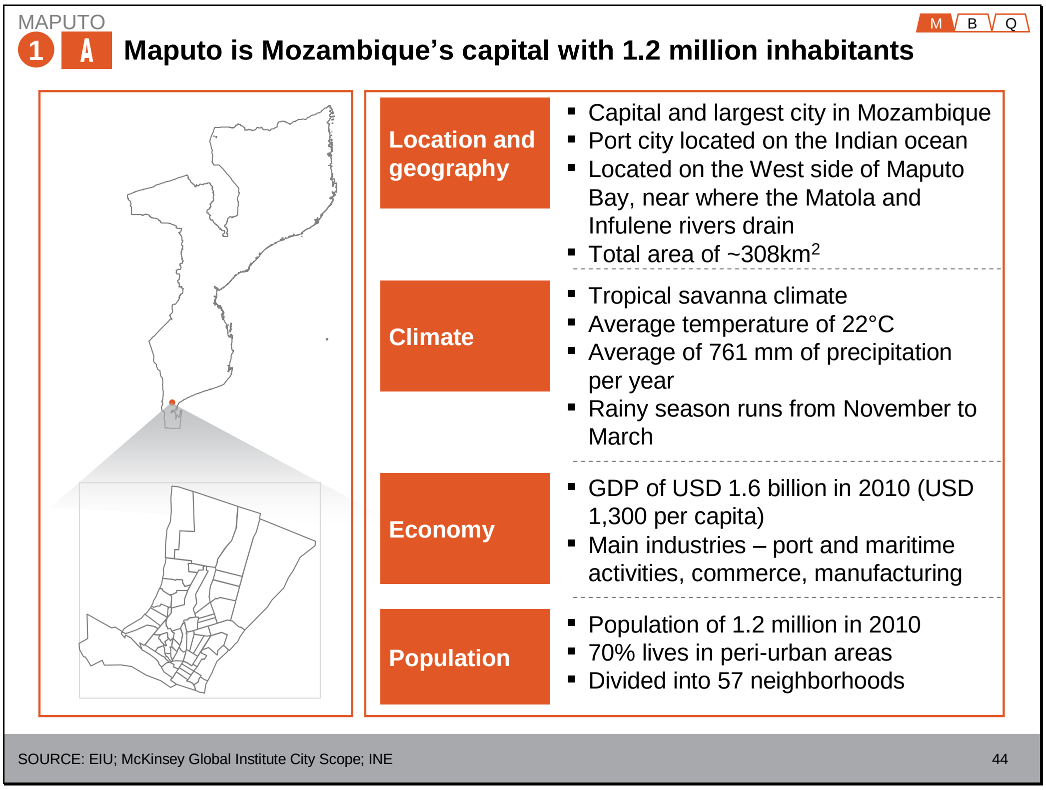
⑤ What are the outcomes and lessons?

- **A** City context
- **B** Natural hazard profile
- **C** Current level of preparedness

- **S** Climate change scenarios
- **H** Hazard module
- **VA** Value of assets module
- **V** Vulnerability module
- **EL** Expected loss assessment and sectoral impacts

SOURCE: INGC Phase II Theme 3

SLIDE 45



MAPUTO

M B Q

1 A Maputo is Mozambique's capital with 1.2 million inhabitants

Location and geography
- Capital and largest city in Mozambique
- Port city located on the Indian ocean
- Located on the West side of Maputo Bay, near where the Matola and Infulene rivers drain
- Total area of ~308km^2

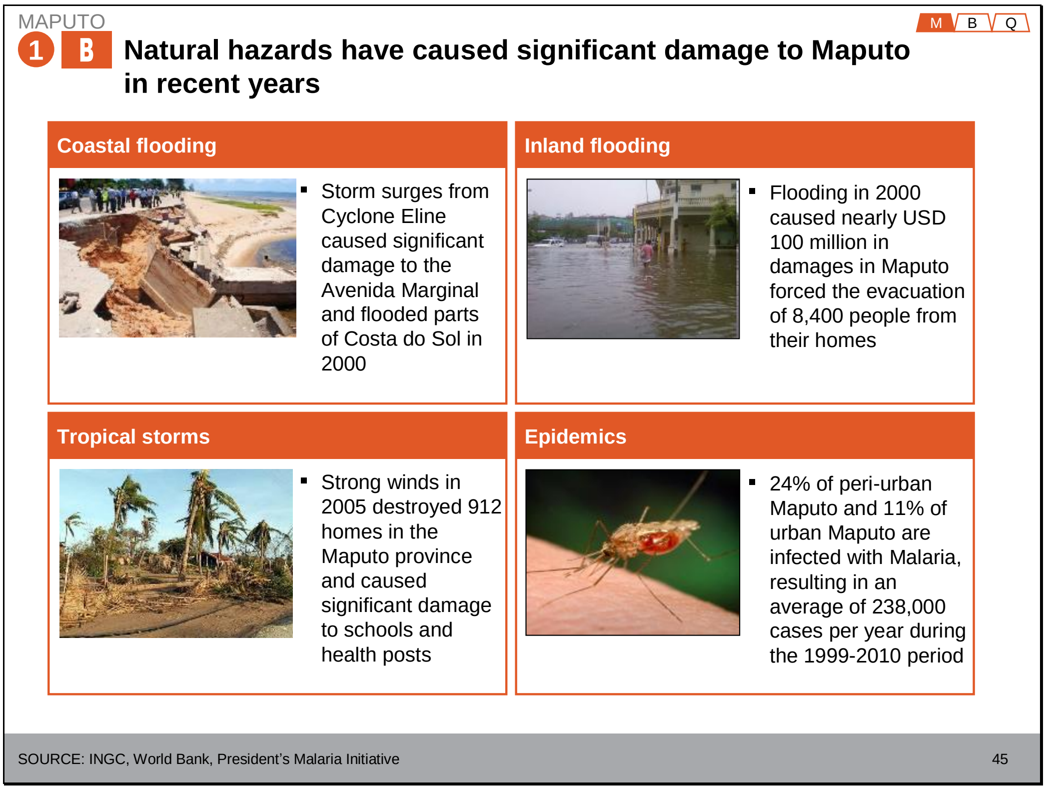
Climate
- Tropical savanna climate
- Average temperature of 22°C
- Average of 761 mm of precipitation per year
- Rainy season runs from November to March

Economy
- GDP of USD 1.6 billion in 2010 (USD 1,300 per capita)
- Main industries – port and maritime activities, commerce, manufacturing

Population
- Population of 1.2 million in 2010
- 70% lives in peri-urban areas
- Divided into 57 neighborhoods

SOURCE: EIU; McKinsey Global Institute City Scope; INE

SLIDE 46



MAPUTO

M B Q

1 B Natural hazards have caused significant damage to Maputo in recent years

Coastal flooding
- Storm surges from Cyclone Eline caused significant damage to the Avenida Marginal and flooded parts of Costa do Sol in 2000

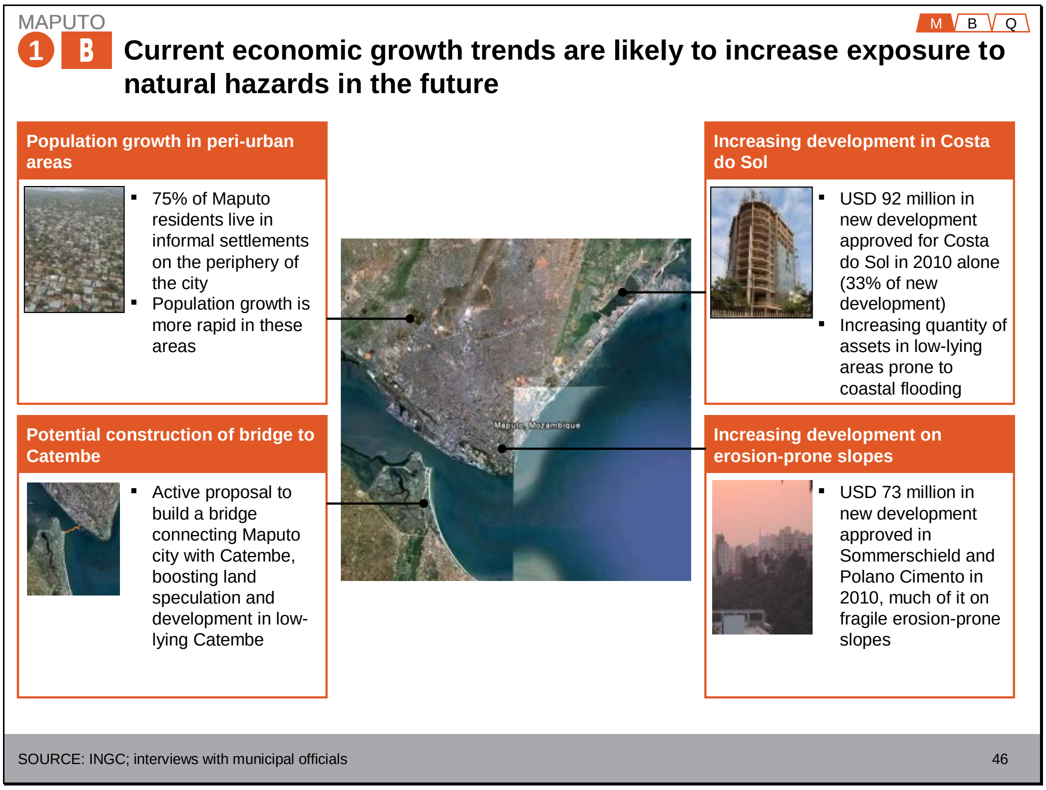
Inland flooding
- Flooding in 2000 caused nearly USD 100 million in damages in Maputo forced the evacuation of 8,400 people from their homes

Tropical storms
- Strong winds in 2005 destroyed 912 homes in the Maputo province and caused significant damage to schools and health posts

Epidemics
- 24% of peri-urban Maputo and 11% of urban Maputo are infected with Malaria, resulting in an average of 238,000 cases per year during the 1999-2010 period

SOURCE: INGC, World Bank, President's Malaria Initiative

SLIDE 47



MAPUTO

1 B

Current economic growth trends are likely to increase exposure to natural hazards in the future

Population growth in peri-urban areas

- 75% of Maputo residents live in informal settlements on the periphery of the city
- Population growth is more rapid in these areas

Increasing development in Costa do Sol

- USD 92 million in new development approved for Costa do Sol in 2010 alone (33% of new development)
- Increasing quantity of assets in low-lying areas prone to coastal flooding

Potential construction of bridge to Catembe

- Active proposal to build a bridge connecting Maputo city with Catembe, boosting land speculation and development in low-lying Catembe

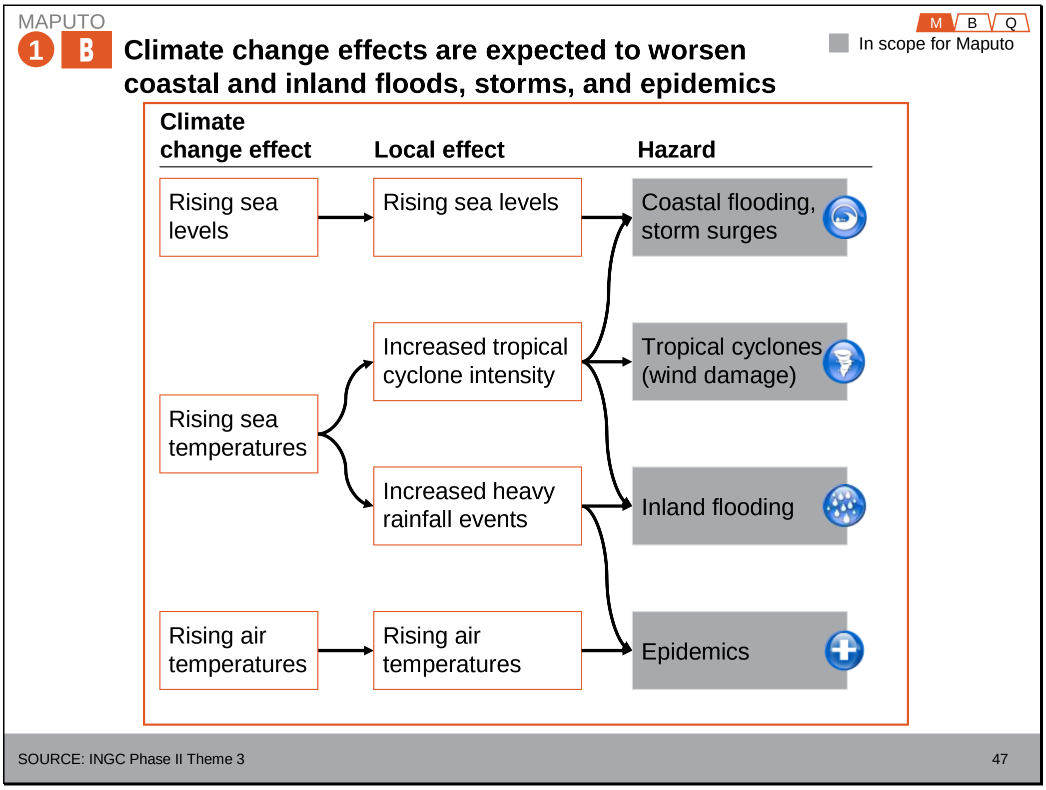
Increasing development on erosion-prone slopes

- USD 73 million in new development approved in Sommerschield and Polano Cimento in 2010, much of it on fragile erosion-prone slopes

SOURCE: INGC; interviews with municipal officials

46

SLIDE 48



MAPUTO

1 B

Climate change effects are expected to worsen coastal and inland floods, storms, and epidemics

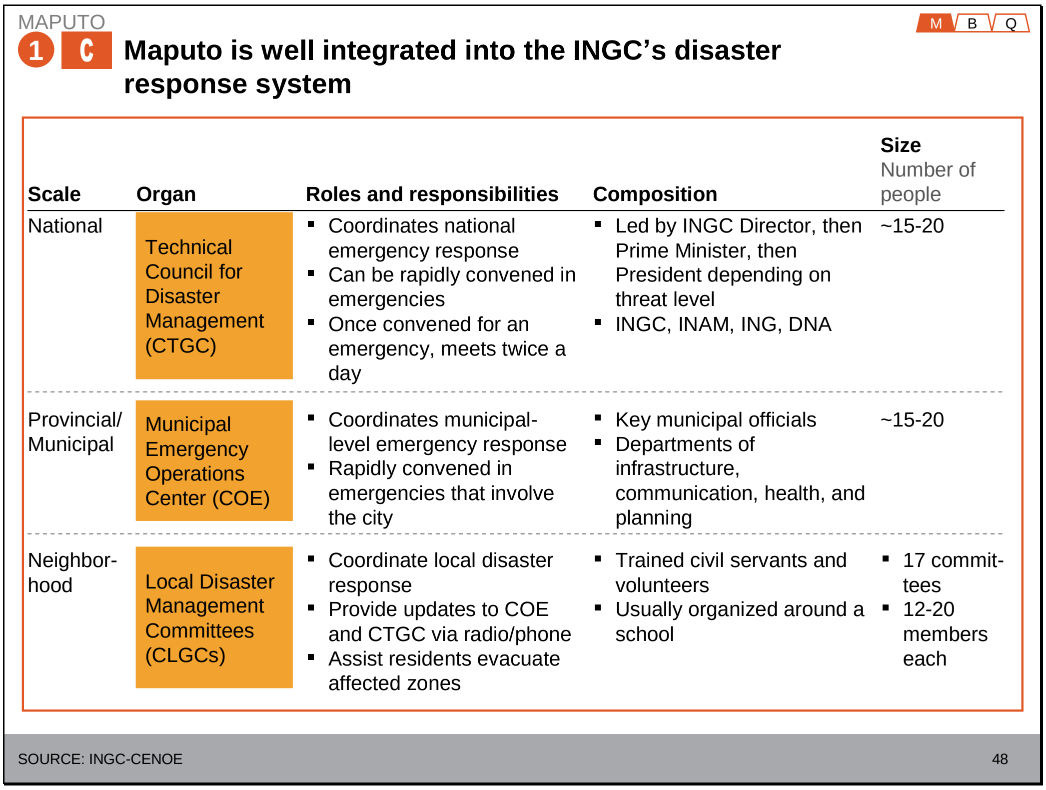
▨ In scope for Maputo

Climate change effect	Local effect	Hazard
Rising sea levels	Rising sea levels	Coastal flooding, storm surges
	Increased tropical cyclone intensity	Tropical cyclones (wind damage)
Rising sea temperatures		
	Increased heavy rainfall events	Inland flooding
Rising air temperatures	Rising air temperatures	Epidemics

SOURCE: INGC Phase II Theme 3

47

SLIDE 49



MAPUTO

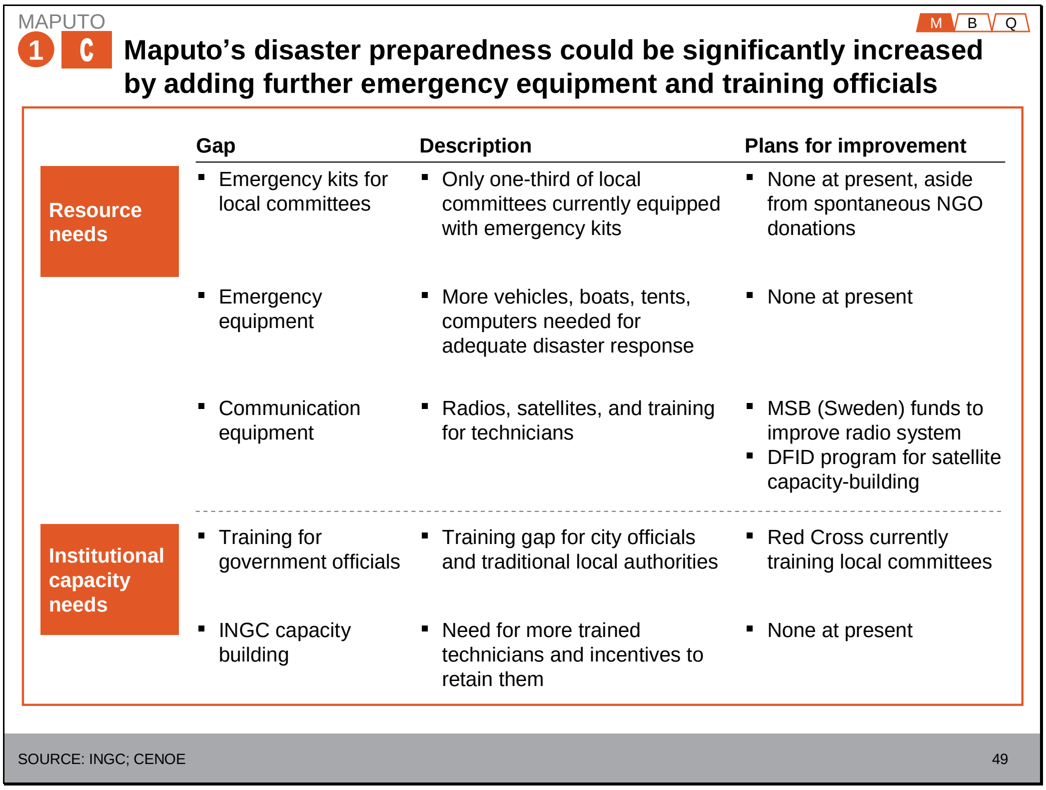
M B Q

1 C Maputo is well integrated into the INGC's disaster response system

Scale	Organ	Roles and responsibilities	Composition	**Size** Number of people
National	Technical Council for Disaster Management (CTGC)	▪ Coordinates national emergency response ▪ Can be rapidly convened in emergencies ▪ Once convened for an emergency, meets twice a day	▪ Led by INGC Director, then Prime Minister, then President depending on threat level ▪ INGC, INAM, ING, DNA	~15-20
Provincial/ Municipal	Municipal Emergency Operations Center (COE)	▪ Coordinates municipal-level emergency response ▪ Rapidly convened in emergencies that involve the city	▪ Key municipal officials ▪ Departments of infrastructure, communication, health, and planning	~15-20
Neighbor-hood	Local Disaster Management Committees (CLGCs)	▪ Coordinate local disaster response ▪ Provide updates to COE and CTGC via radio/phone ▪ Assist residents evacuate affected zones	▪ Trained civil servants and volunteers ▪ Usually organized around a school	▪ 17 commit-tees ▪ 12-20 members each

SOURCE: INGC-CENOE

SLIDE 50



MAPUTO

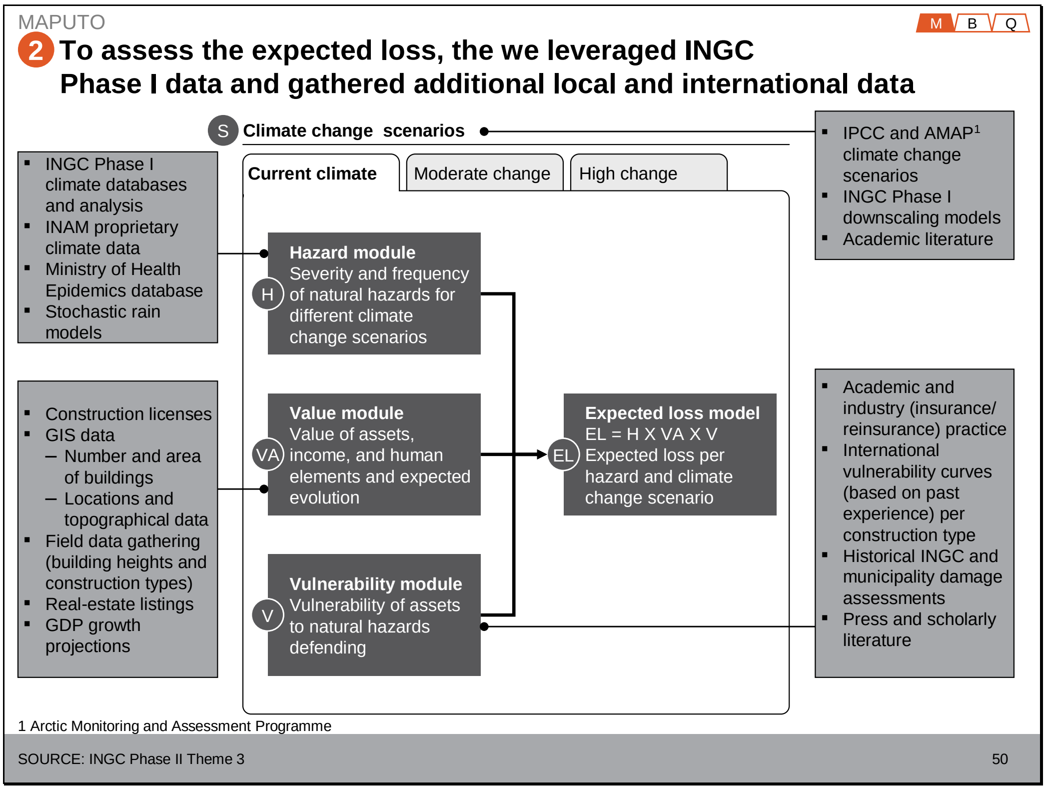
M B Q

1 C Maputo's disaster preparedness could be significantly increased by adding further emergency equipment and training officials

	Gap	Description	Plans for improvement
Resource needs	▪ Emergency kits for local committees	▪ Only one-third of local committees currently equipped with emergency kits	▪ None at present, aside from spontaneous NGO donations
	▪ Emergency equipment	▪ More vehicles, boats, tents, computers needed for adequate disaster response	▪ None at present
	▪ Communication equipment	▪ Radios, satellites, and training for technicians	▪ MSB (Sweden) funds to improve radio system ▪ DFID program for satellite capacity-building
Institutional capacity needs	▪ Training for government officials	▪ Training gap for city officials and traditional local authorities	▪ Red Cross currently training local committees
	▪ INGC capacity building	▪ Need for more trained technicians and incentives to retain them	▪ None at present

SOURCE: INGC; CENOE

SLIDE 51



MAPUTO

M B Q

② To assess the expected loss, the we leveraged INGC Phase I data and gathered additional local and international data

S Climate change scenarios

- IPCC and AMAP[1] climate change scenarios
- INGC Phase I downscaling models
- Academic literature

- INGC Phase I climate databases and analysis
- INAM proprietary climate data
- Ministry of Health Epidemics database
- Stochastic rain models

H Hazard module
Severity and frequency of natural hazards for different climate change scenarios

- Construction licenses
- GIS data
  - Number and area of buildings
  - Locations and topographical data
- Field data gathering (building heights and construction types)
- Real-estate listings
- GDP growth projections

VA Value module
Value of assets, income, and human elements and expected evolution

EL Expected loss model
EL = H X VA X V
Expected loss per hazard and climate change scenario

V Vulnerability module
Vulnerability of assets to natural hazards defending

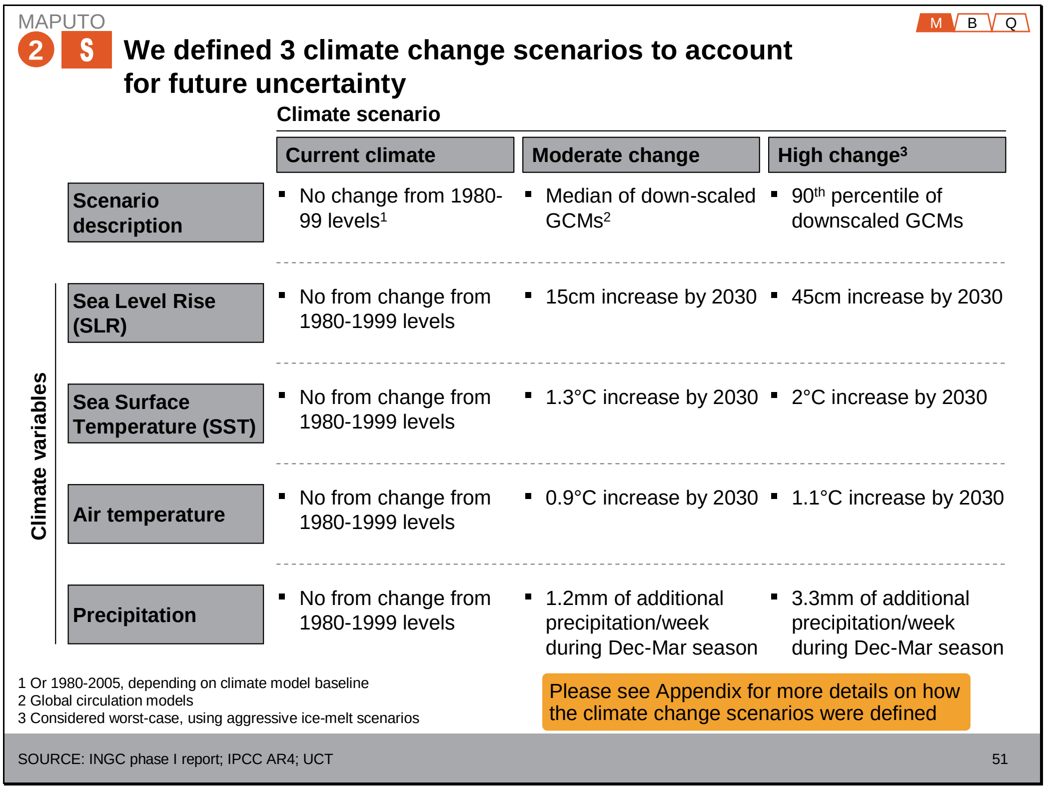
- Academic and industry (insurance/ reinsurance) practice
- International vulnerability curves (based on past experience) per construction type
- Historical INGC and municipality damage assessments
- Press and scholarly literature

1 Arctic Monitoring and Assessment Programme

SOURCE: INGC Phase II Theme 3

50

SLIDE 52



MAPUTO

M B Q

② S We defined 3 climate change scenarios to account for future uncertainty

Climate scenario

Climate variables		Current climate	Moderate change	High change[3]
	Scenario description	No change from 1980-99 levels[1]	Median of down-scaled GCMs[2]	90th percentile of downscaled GCMs
Climate variables	**Sea Level Rise (SLR)**	No from change from 1980-1999 levels	15cm increase by 2030	45cm increase by 2030
	Sea Surface Temperature (SST)	No from change from 1980-1999 levels	1.3°C increase by 2030	2°C increase by 2030
	Air temperature	No from change from 1980-1999 levels	0.9°C increase by 2030	1.1°C increase by 2030
	Precipitation	No from change from 1980-1999 levels	1.2mm of additional precipitation/week during Dec-Mar season	3.3mm of additional precipitation/week during Dec-Mar season

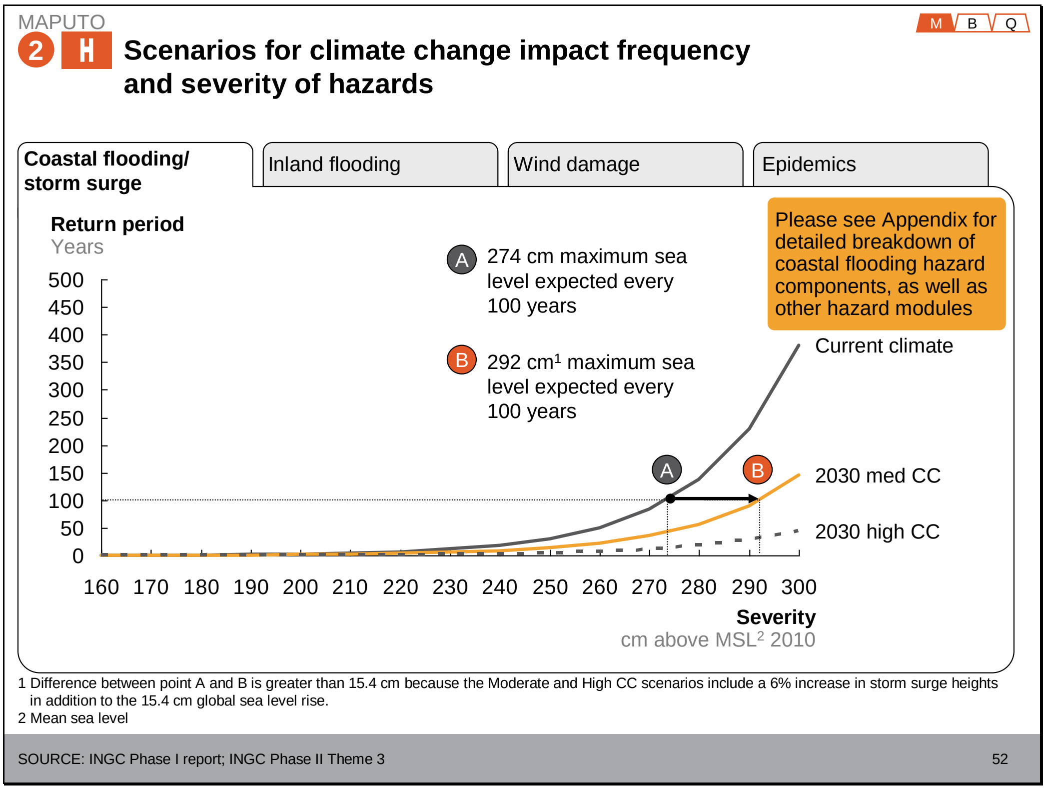
1 Or 1980-2005, depending on climate model baseline
2 Global circulation models
3 Considered worst-case, using aggressive ice-melt scenarios

Please see Appendix for more details on how the climate change scenarios were defined

SOURCE: INGC phase I report; IPCC AR4; UCT

51

SLIDE 53



MAPUTO

2 H Scenarios for climate change impact frequency and severity of hazards

M B Q

Coastal flooding/ storm surge | Inland flooding | Wind damage | Epidemics

Please see Appendix for detailed breakdown of coastal flooding hazard components, as well as other hazard modules

Ⓐ 274 cm maximum sea level expected every 100 years

Ⓑ 292 cm^1 maximum sea level expected every 100 years

1 Difference between point A and B is greater than 15.4 cm because the Moderate and High CC scenarios include a 6% increase in storm surge heights in addition to the 15.4 cm global sea level rise.
2 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II Theme 3

NOTES FOR SLIDE 53:

D1 – Magnitude of Expected Loss – Hazard Module – Coastal Flooding and Storm Surge

Scenarios for climate change impact frequency and severity of hazards.

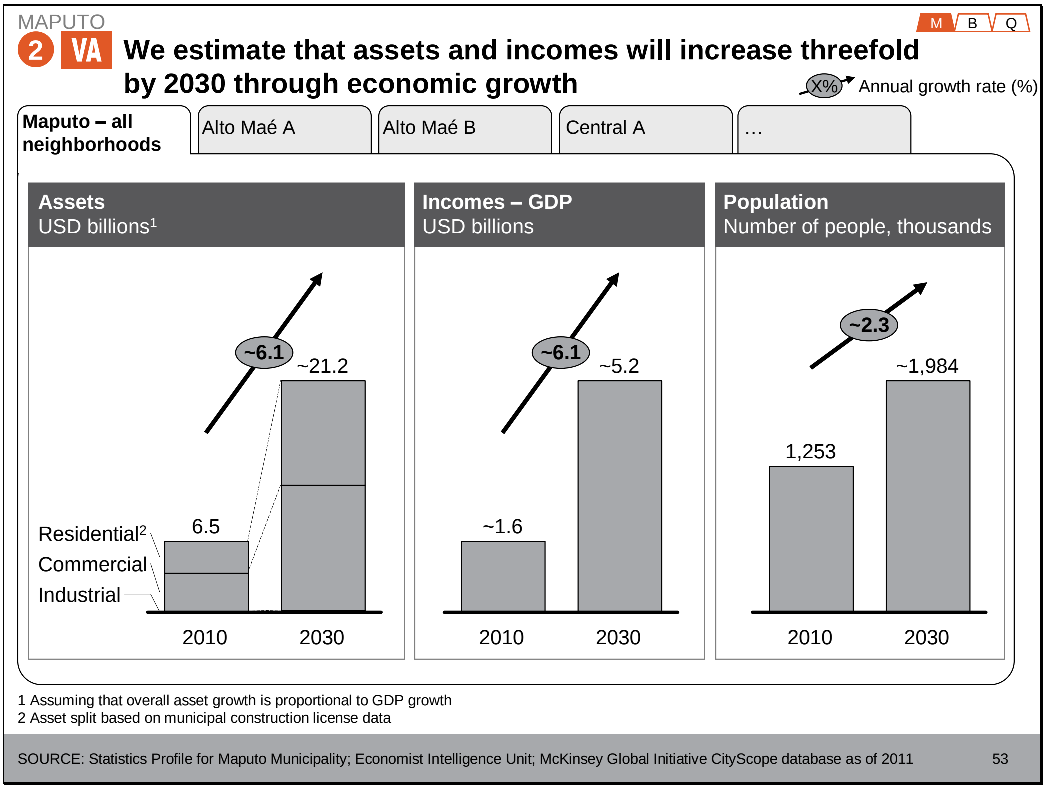
The frequency and severity of high level storm surges are compared for a number of different climate change scenarios for 2030.

The X axis charts the severity of the storm surge, meaning how many centimeters the 2010 Mean Sea Level the coastal waters will rise during a storm. The Y axis charts the “Return period”, or frequency with which the event is likely to take place. The lines are the projections for the three modeled climate scenarios, a continuation of current climate, and a medium and high scenario.

Taken together, any point on one of these curves shows how often it is likely that storm surge will reach a particular level. A 100 year line is shown to indicate that that, if Current climate were to continue, a 274cm above MSL rise could be predicted once every hundred years.

The increasing severity of storm surges projected by 2030 is shown in the increasing cm rise projected every 100 years for the two more pessimistic climate scenario lines. For the 2030 medium climate change scenario, once in a 100 year storm surge increases to 292 cm above MSL, and 2030 high climate change will result in a significantly higher 100 year return storm surge.

SLIDE 54



MAPUTO

M B Q

2 VA **We estimate that assets and incomes will increase threefold by 2030 through economic growth**

X% Annual growth rate (%)

Maputo – all neighborhoods | Alto Maé A | Alto Maé B | Central A | …

Assets
USD billions[1]

Residential[2]
Commercial
Industrial

6.5 (2010) → ~21.2 (2030), ~6.1

Incomes – GDP
USD billions

~1.6 (2010) → ~5.2 (2030), ~6.1

Population
Number of people, thousands

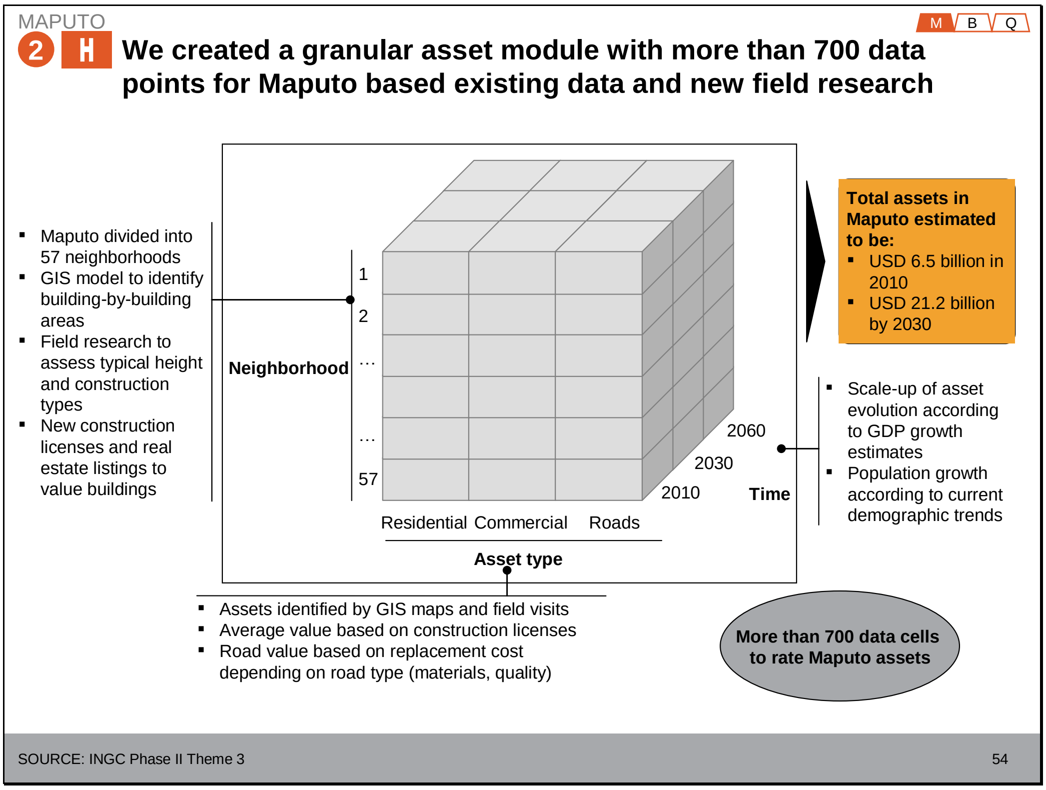
1,253 (2010) → ~1,984 (2030), ~2.3

[1] Assuming that overall asset growth is proportional to GDP growth
[2] Asset split based on municipal construction license data

SOURCE: Statistics Profile for Maputo Municipality; Economist Intelligence Unit; McKinsey Global Initiative CityScope database as of 2011

53

SLIDE 55



MAPUTO

M B Q

2 H **We created a granular asset module with more than 700 data points for Maputo based existing data and new field research**

- Maputo divided into 57 neighborhoods
- GIS model to identify building-by-building areas
- Field research to assess typical height and construction types
- New construction licenses and real estate listings to value buildings

Total assets in Maputo estimated to be:
- USD 6.5 billion in 2010
- USD 21.2 billion by 2030

- Scale-up of asset evolution according to GDP growth estimates
- Population growth according to current demographic trends

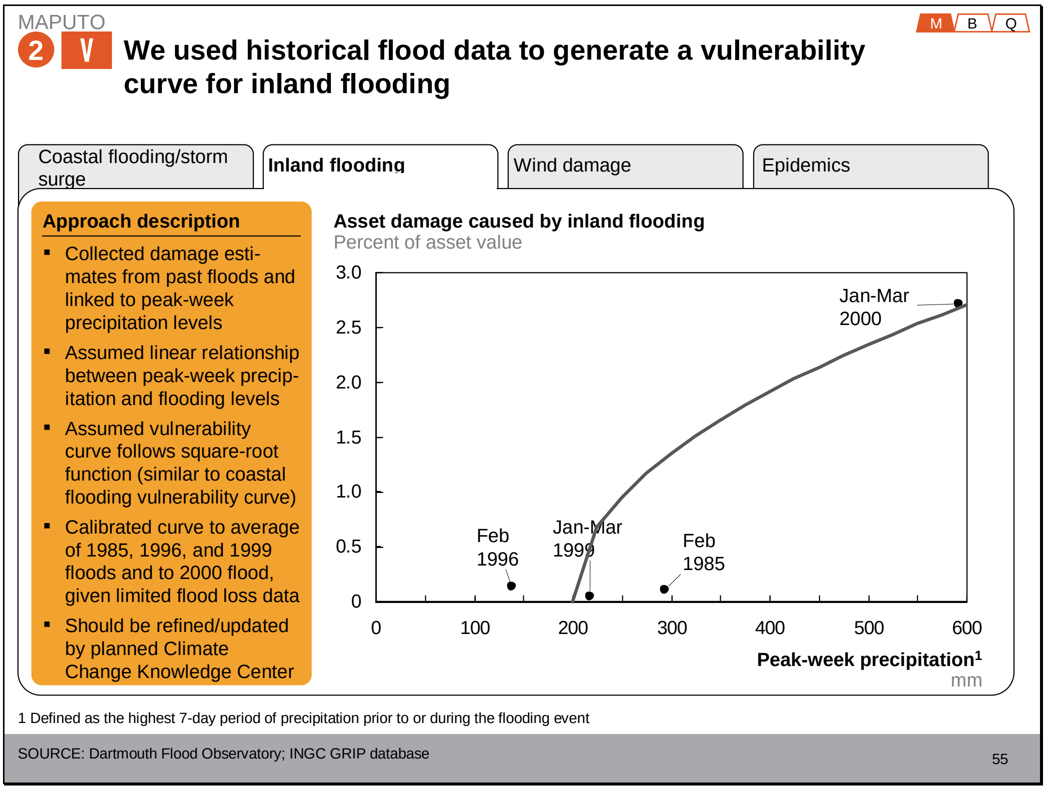
- Assets identified by GIS maps and field visits
- Average value based on construction licenses
- Road value based on replacement cost depending on road type (materials, quality)

More than 700 data cells to rate Maputo assets

SOURCE: INGC Phase II Theme 3

54

SLIDE 56



MAPUTO

2 V **We used historical flood data to generate a vulnerability curve for inland flooding**

Coastal flooding/storm surge | **Inland flooding** | Wind damage | Epidemics

Approach description

- Collected damage estimates from past floods and linked to peak-week precipitation levels
- Assumed linear relationship between peak-week precipitation and flooding levels
- Assumed vulnerability curve follows square-root function (similar to coastal flooding vulnerability curve)
- Calibrated curve to average of 1985, 1996, and 1999 floods and to 2000 flood, given limited flood loss data
- Should be refined/updated by planned Climate Change Knowledge Center

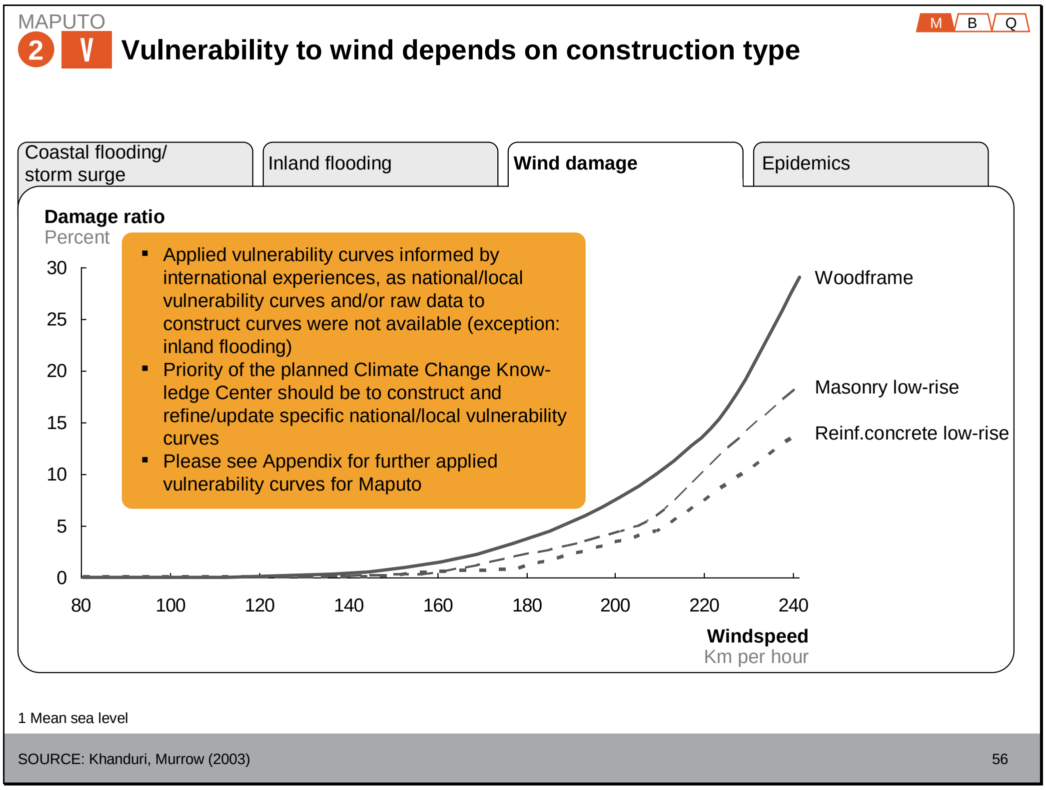
Asset damage caused by inland flooding
Percent of asset value

Peak-week precipitation[1]
mm

[1] Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: Dartmouth Flood Observatory; INGC GRIP database

SLIDE 57



MAPUTO

2 V **Vulnerability to wind depends on construction type**

Coastal flooding/ storm surge | Inland flooding | **Wind damage** | Epidemics

Damage ratio
Percent

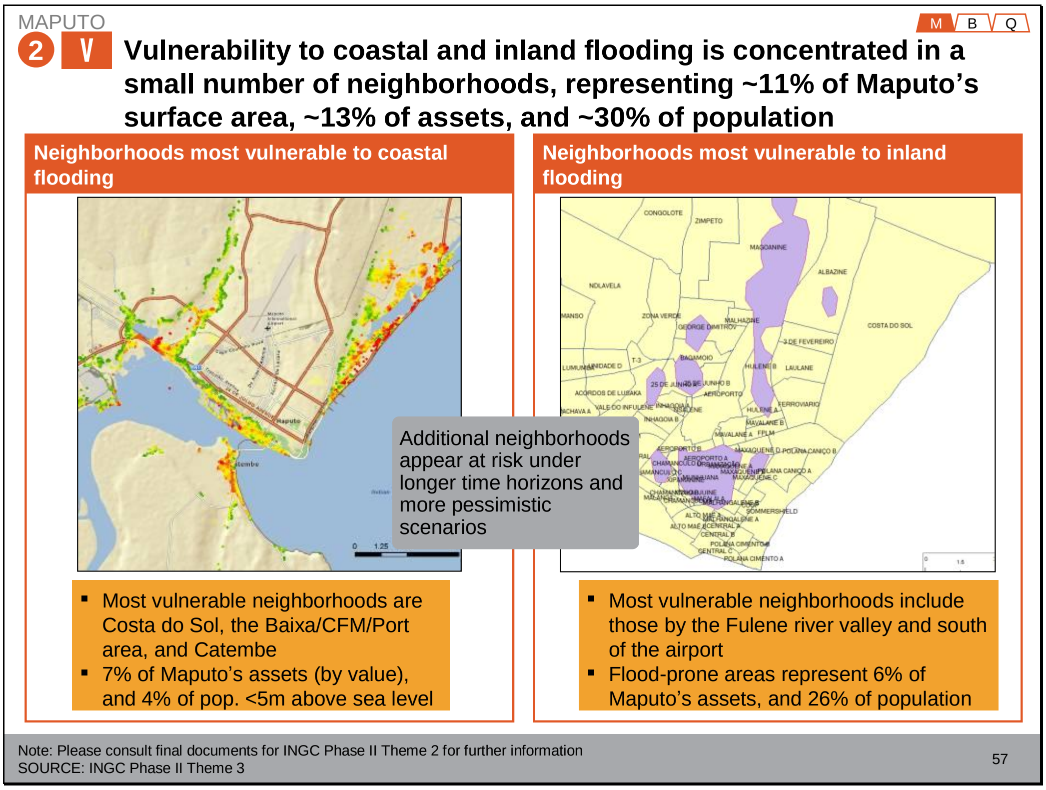
- Applied vulnerability curves informed by international experiences, as national/local vulnerability curves and/or raw data to construct curves were not available (exception: inland flooding)
- Priority of the planned Climate Change Knowledge Center should be to construct and refine/update specific national/local vulnerability curves
- Please see Appendix for further applied vulnerability curves for Maputo

Windspeed
Km per hour

1 Mean sea level

SOURCE: Khanduri, Murrow (2003)

SLIDE 58



MAPUTO

M B Q

2 V

Vulnerability to coastal and inland flooding is concentrated in a small number of neighborhoods, representing ~11% of Maputo's surface area, ~13% of assets, and ~30% of population

Neighborhoods most vulnerable to coastal flooding

- Most vulnerable neighborhoods are Costa do Sol, the Baixa/CFM/Port area, and Catembe
- 7% of Maputo's assets (by value), and 4% of pop. <5m above sea level

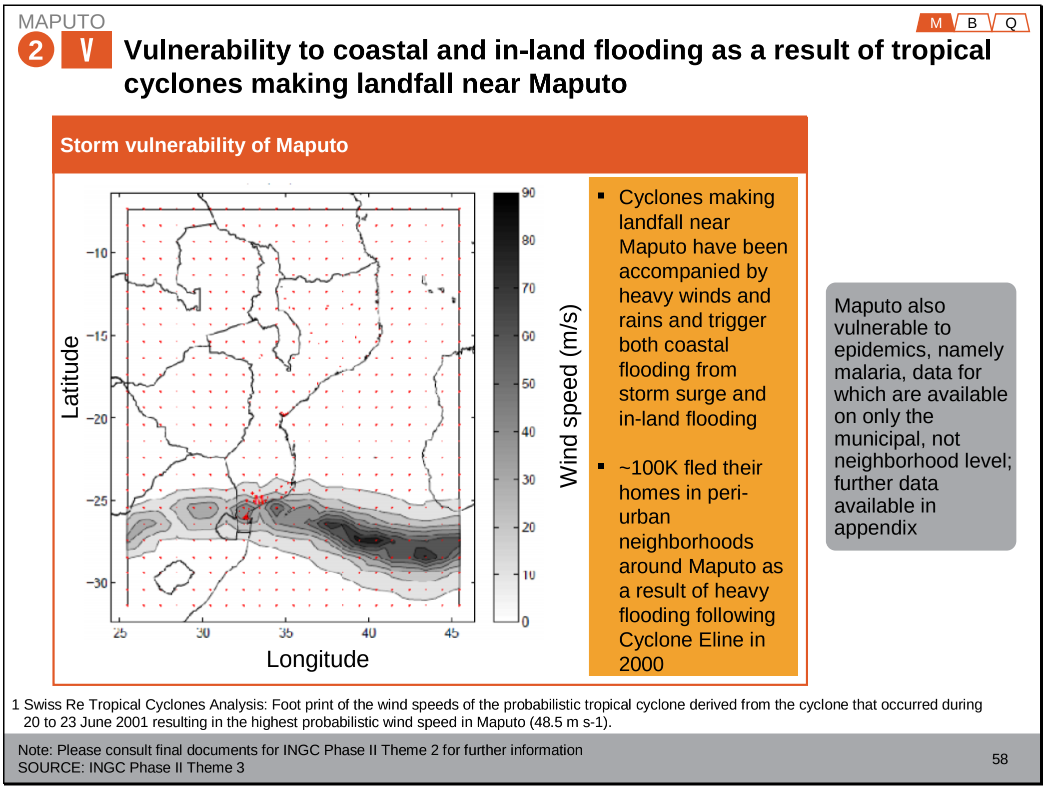
Additional neighborhoods appear at risk under longer time horizons and more pessimistic scenarios

Neighborhoods most vulnerable to inland flooding

- Most vulnerable neighborhoods include those by the Fulene river valley and south of the airport
- Flood-prone areas represent 6% of Maputo's assets, and 26% of population

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 59



MAPUTO

M B Q

2 V

Vulnerability to coastal and in-land flooding as a result of tropical cyclones making landfall near Maputo

Storm vulnerability of Maputo

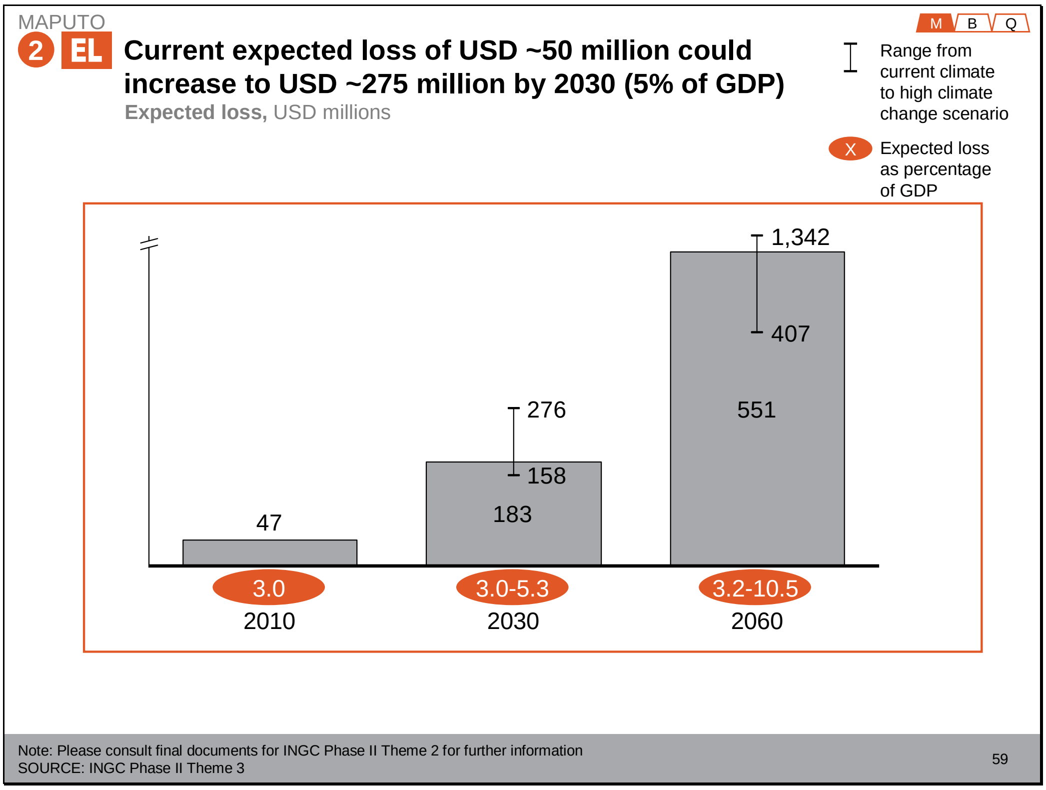
- Cyclones making landfall near Maputo have been accompanied by heavy winds and rains and trigger both coastal flooding from storm surge and in-land flooding
- ~100K fled their homes in peri-urban neighborhoods around Maputo as a result of heavy flooding following Cyclone Eline in 2000

Maputo also vulnerable to epidemics, namely malaria, data for which are available on only the municipal, not neighborhood level; further data available in appendix

1 Swiss Re Tropical Cyclones Analysis: Foot print of the wind speeds of the probabilistic tropical cyclone derived from the cyclone that occurred during 20 to 23 June 2001 resulting in the highest probabilistic wind speed in Maputo (48.5 m s-1).

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 60



MAPUTO

Current expected loss of USD ~50 million could increase to USD ~275 million by 2030 (5% of GDP)

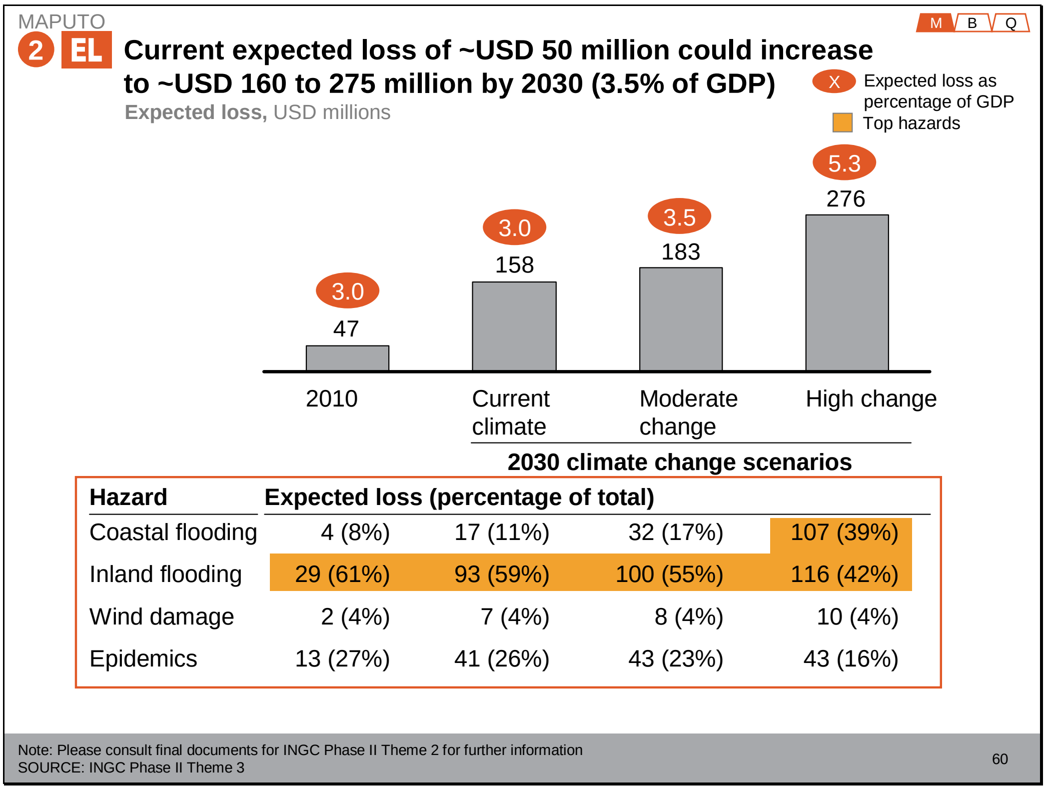
Expected loss, USD millions

Range from current climate to high climate change scenario

X Expected loss as percentage of GDP

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 61



MAPUTO

Current expected loss of ~USD 50 million could increase to ~USD 160 to 275 million by 2030 (3.5% of GDP)

Expected loss, USD millions

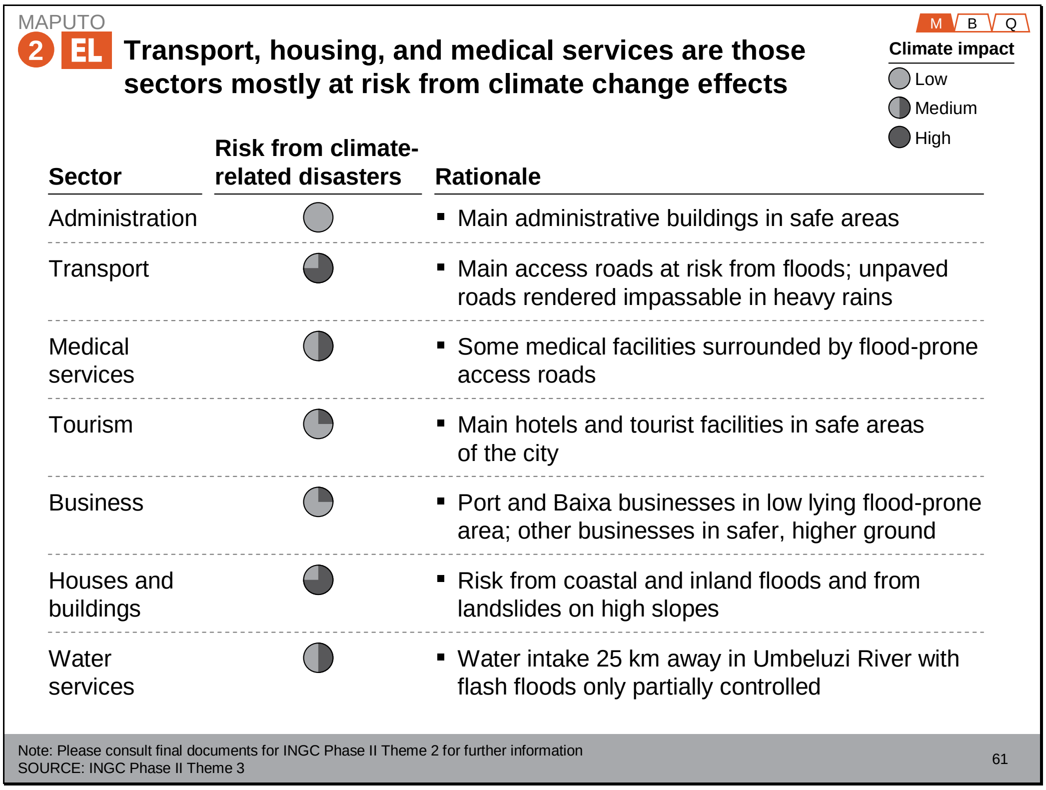
X Expected loss as percentage of GDP

🟧 Top hazards

Hazard	Expected loss (percentage of total)			
Coastal flooding	4 (8%)	17 (11%)	32 (17%)	107 (39%)
Inland flooding	29 (61%)	93 (59%)	100 (55%)	116 (42%)
Wind damage	2 (4%)	7 (4%)	8 (4%)	10 (4%)
Epidemics	13 (27%)	41 (26%)	43 (23%)	43 (16%)

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 62



MAPUTO

② EL Transport, housing, and medical services are those sectors mostly at risk from climate change effects

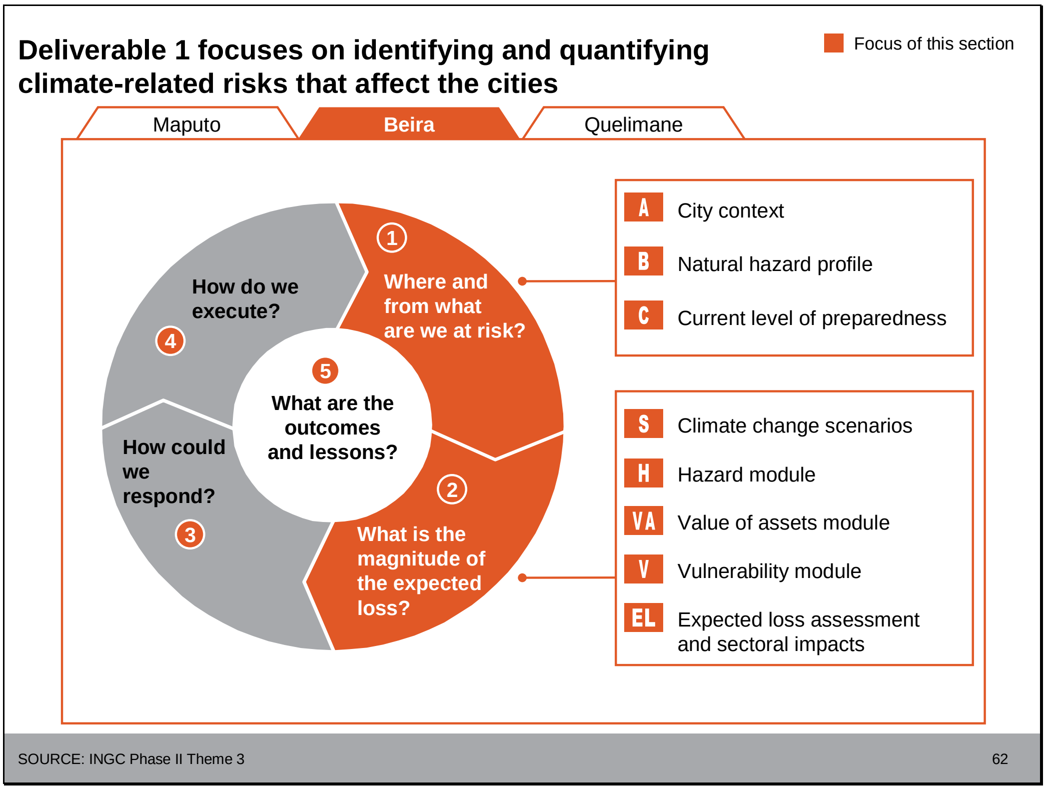
M | B | Q

Climate impact
○ Low
◑ Medium
● High

Sector	Risk from climate-related disasters	Rationale
Administration	○	▪ Main administrative buildings in safe areas
Transport	◕	▪ Main access roads at risk from floods; unpaved roads rendered impassable in heavy rains
Medical services	◑	▪ Some medical facilities surrounded by flood-prone access roads
Tourism	◔	▪ Main hotels and tourist facilities in safe areas of the city
Business	◔	▪ Port and Baixa businesses in low lying flood-prone area; other businesses in safer, higher ground
Houses and buildings	◕	▪ Risk from coastal and inland floods and from landslides on high slopes
Water services	◑	▪ Water intake 25 km away in Umbeluzi River with flash floods only partially controlled

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 63



Deliverable 1 focuses on identifying and quantifying climate-related risks that affect the cities

🟥 Focus of this section

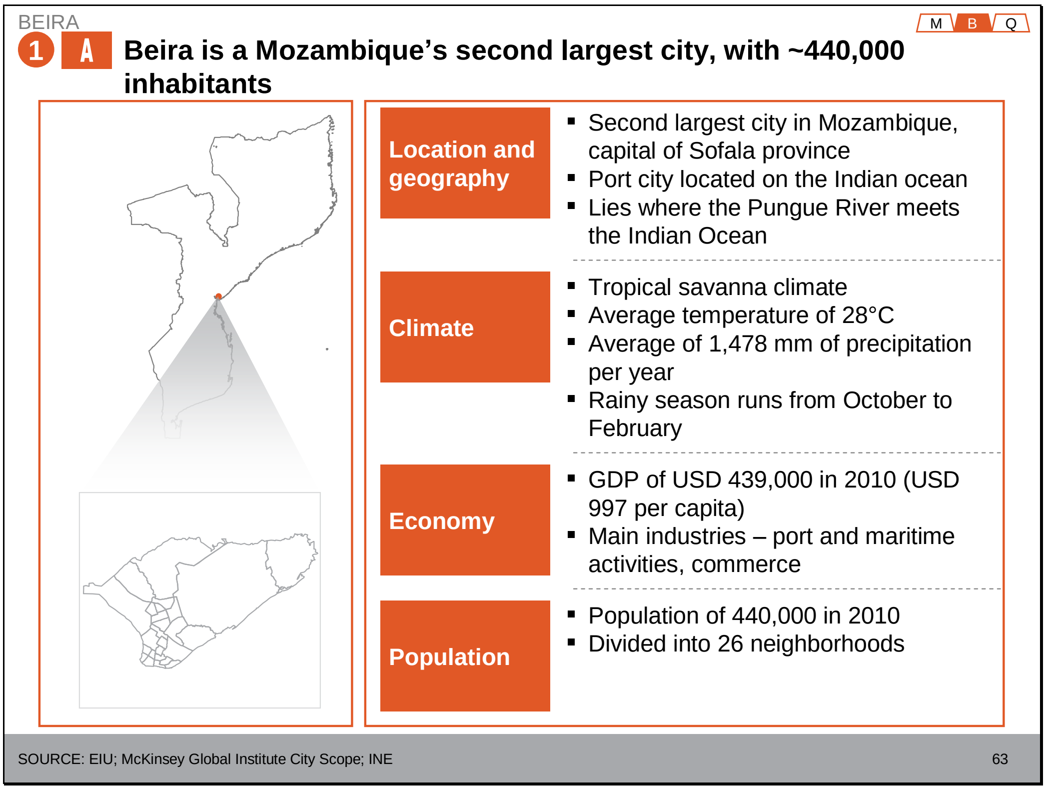
Maputo | **Beira** | Quelimane

A City context
B Natural hazard profile
C Current level of preparedness

S Climate change scenarios
H Hazard module
VA Value of assets module
V Vulnerability module
EL Expected loss assessment and sectoral impacts

SOURCE: INGC Phase II Theme 3

SLIDE 64



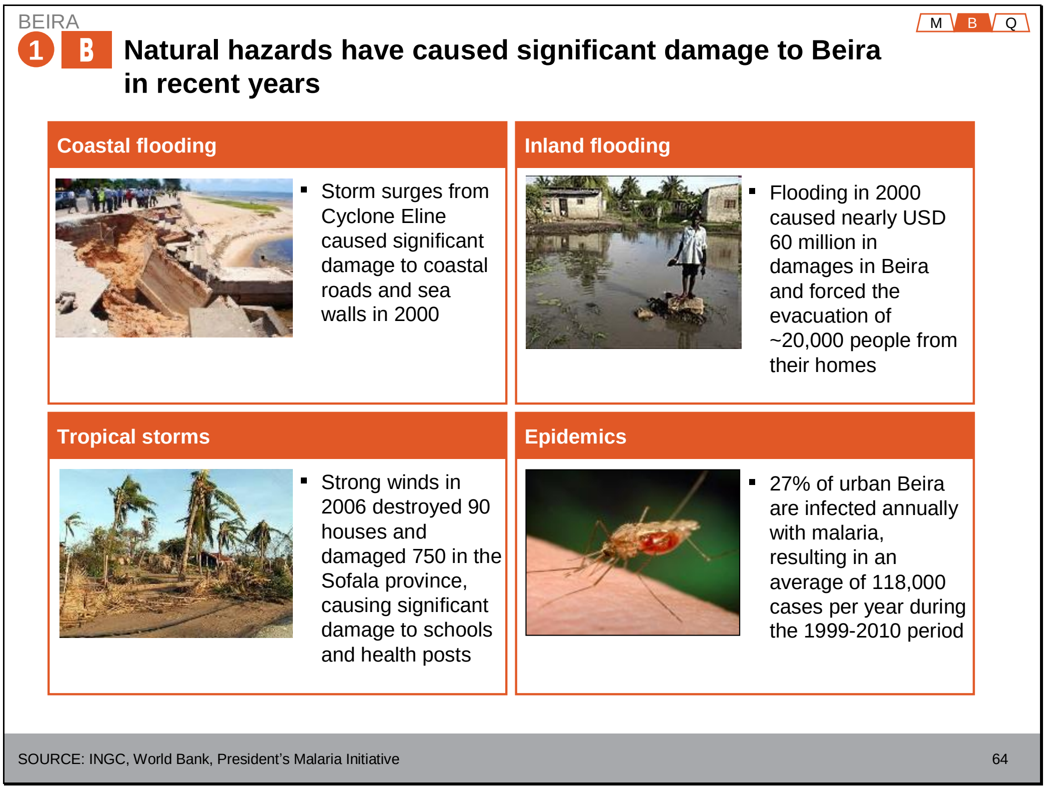
BEIRA

1 A Beira is a Mozambique's second largest city, with ~440,000 inhabitants

Location and geography	▪ Second largest city in Mozambique, capital of Sofala province ▪ Port city located on the Indian ocean ▪ Lies where the Pungue River meets the Indian Ocean
Climate	▪ Tropical savanna climate ▪ Average temperature of 28°C ▪ Average of 1,478 mm of precipitation per year ▪ Rainy season runs from October to February
Economy	▪ GDP of USD 439,000 in 2010 (USD 997 per capita) ▪ Main industries – port and maritime activities, commerce
Population	▪ Population of 440,000 in 2010 ▪ Divided into 26 neighborhoods

SOURCE: EIU; McKinsey Global Institute City Scope; INE

SLIDE 65



BEIRA

1 B Natural hazards have caused significant damage to Beira in recent years

Coastal flooding

- Storm surges from Cyclone Eline caused significant damage to coastal roads and sea walls in 2000

Inland flooding

- Flooding in 2000 caused nearly USD 60 million in damages in Beira and forced the evacuation of ~20,000 people from their homes

Tropical storms

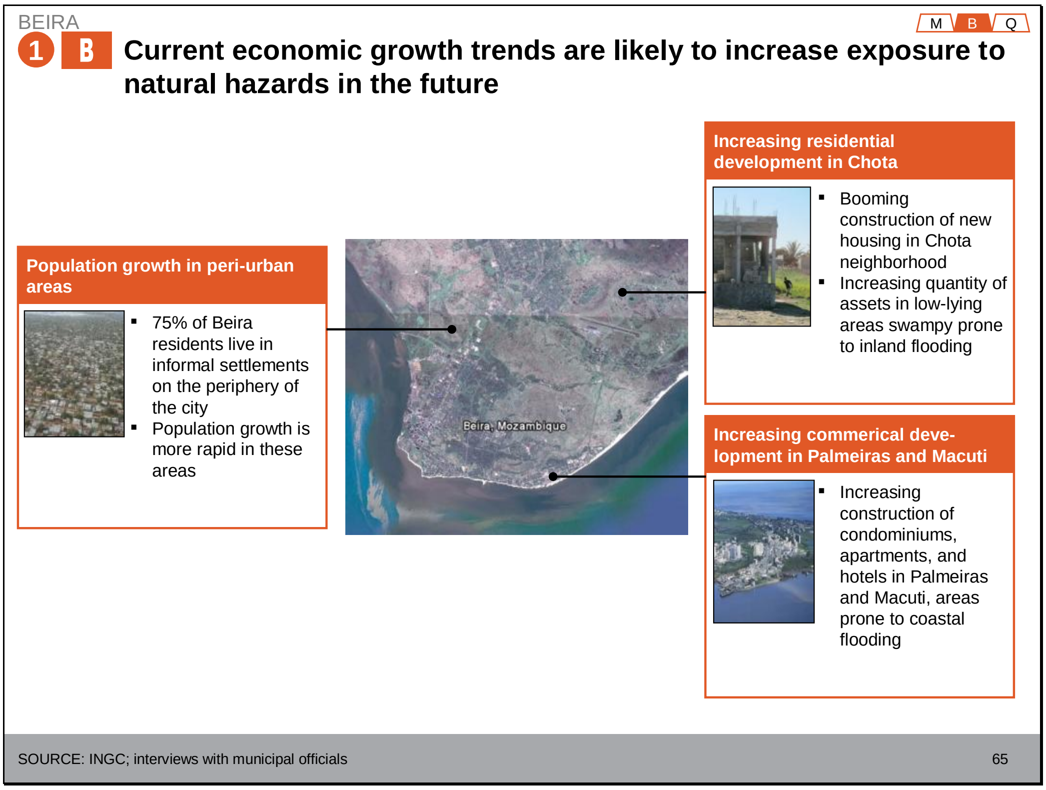
- Strong winds in 2006 destroyed 90 houses and damaged 750 in the Sofala province, causing significant damage to schools and health posts

Epidemics

- 27% of urban Beira are infected annually with malaria, resulting in an average of 118,000 cases per year during the 1999-2010 period

SOURCE: INGC, World Bank, President's Malaria Initiative

SLIDE 66



BEIRA

M B Q

1 B Current economic growth trends are likely to increase exposure to natural hazards in the future

Population growth in peri-urban areas

- 75% of Beira residents live in informal settlements on the periphery of the city
- Population growth is more rapid in these areas

Increasing residential development in Chota

- Booming construction of new housing in Chota neighborhood
- Increasing quantity of assets in low-lying areas swampy prone to inland flooding

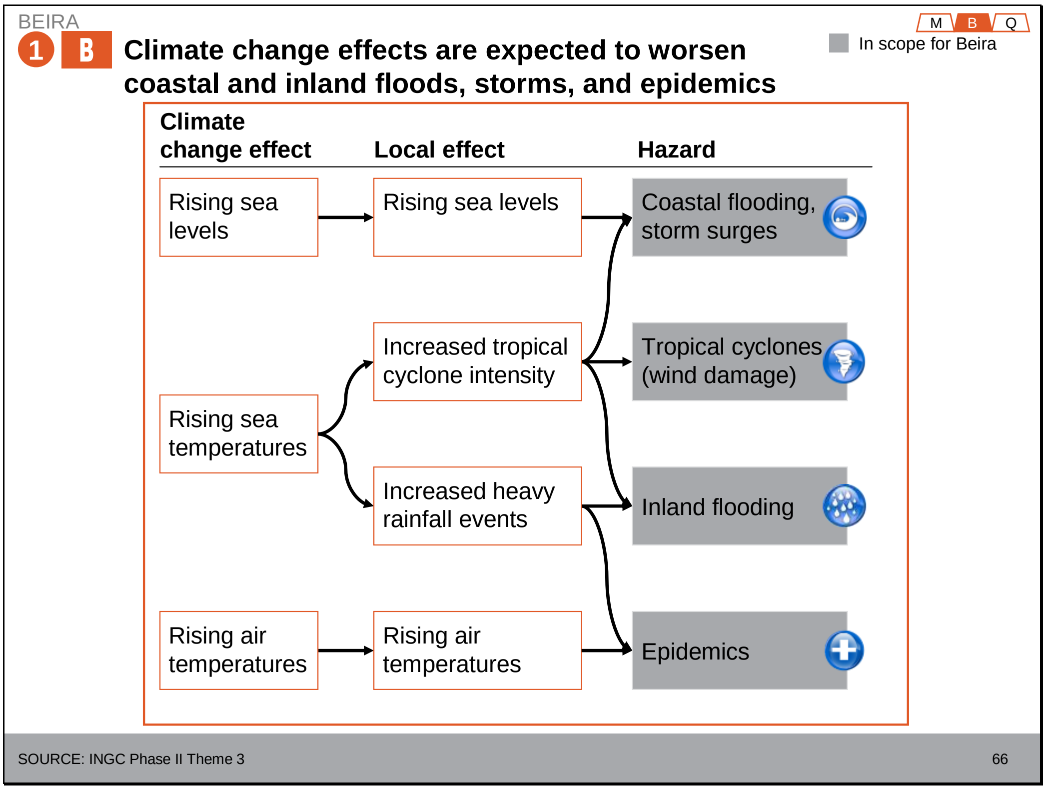
Increasing commerical development in Palmeiras and Macuti

- Increasing construction of condominiums, apartments, and hotels in Palmeiras and Macuti, areas prone to coastal flooding

SOURCE: INGC; interviews with municipal officials

65

SLIDE 67



BEIRA

M B Q

▨ In scope for Beira

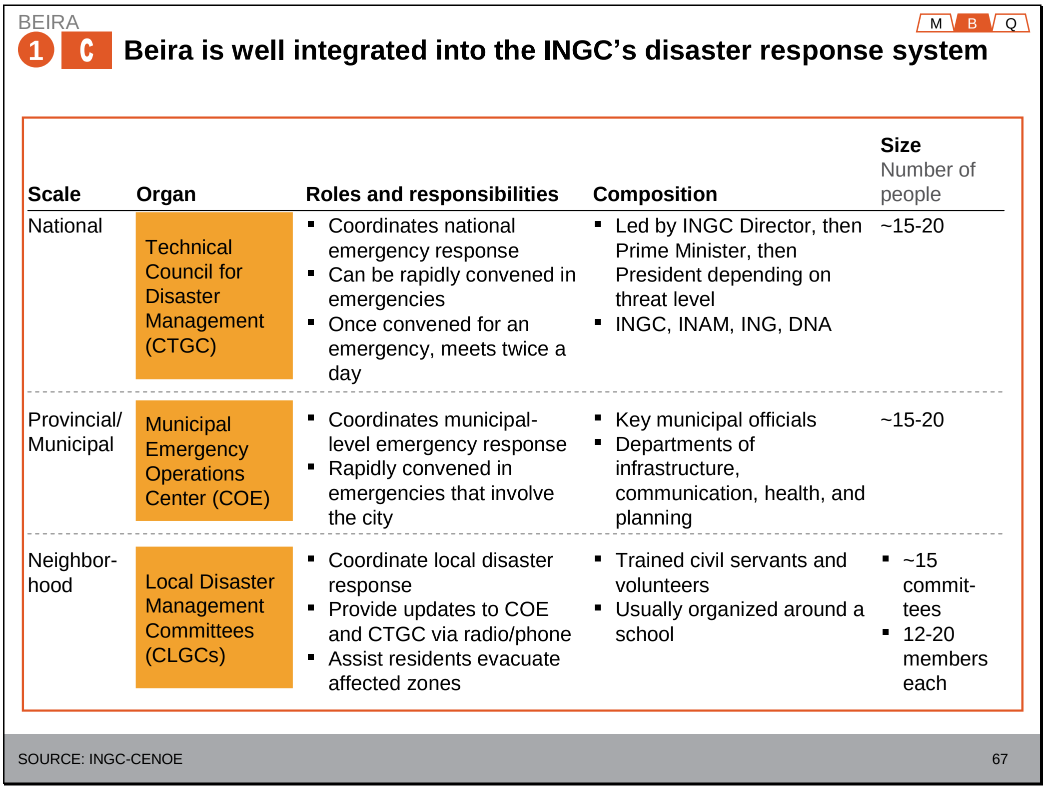
1 B Climate change effects are expected to worsen coastal and inland floods, storms, and epidemics

Climate change effect	Local effect	Hazard
Rising sea levels	Rising sea levels	Coastal flooding, storm surges
	Increased tropical cyclone intensity	Tropical cyclones (wind damage)
Rising sea temperatures	Increased heavy rainfall events	Inland flooding
Rising air temperatures	Rising air temperatures	Epidemics

SOURCE: INGC Phase II Theme 3

66

SLIDE 68



BEIRA

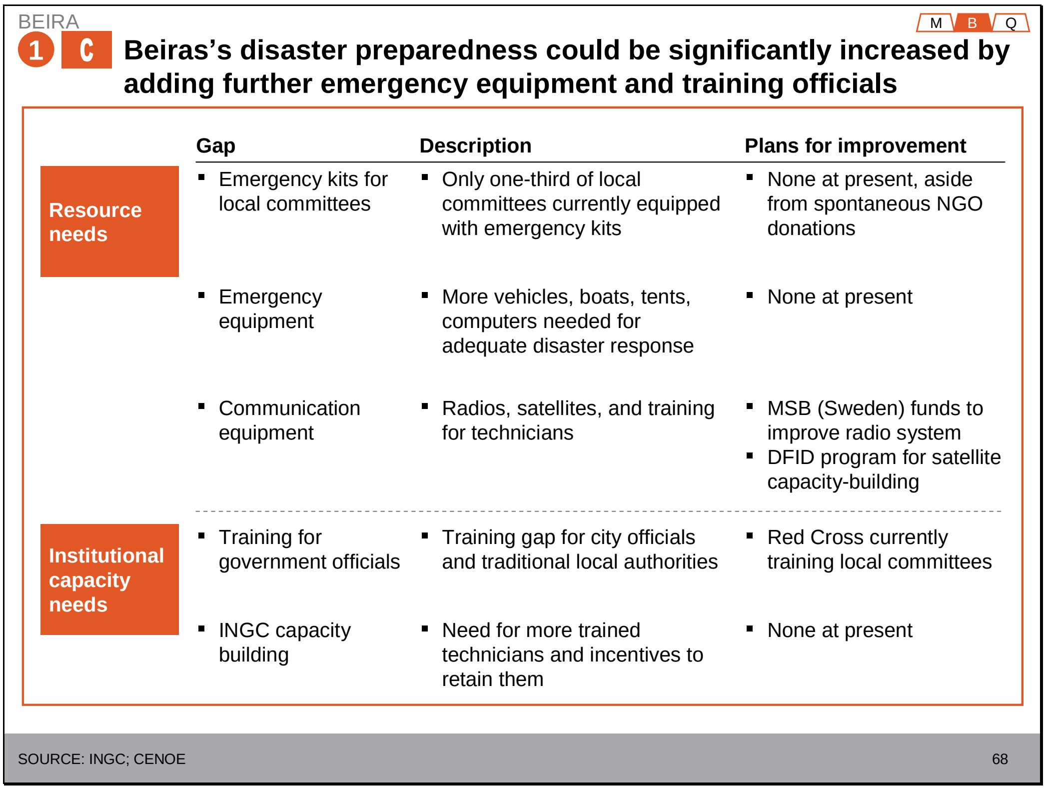
M B Q

1 C Beira is well integrated into the INGC's disaster response system

Scale	Organ	Roles and responsibilities	Composition	**Size** Number of people
National	Technical Council for Disaster Management (CTGC)	▪ Coordinates national emergency response ▪ Can be rapidly convened in emergencies ▪ Once convened for an emergency, meets twice a day	▪ Led by INGC Director, then Prime Minister, then President depending on threat level ▪ INGC, INAM, ING, DNA	~15-20
Provincial/ Municipal	Municipal Emergency Operations Center (COE)	▪ Coordinates municipal-level emergency response ▪ Rapidly convened in emergencies that involve the city	▪ Key municipal officials ▪ Departments of infrastructure, communication, health, and planning	~15-20
Neighbor-hood	Local Disaster Management Committees (CLGCs)	▪ Coordinate local disaster response ▪ Provide updates to COE and CTGC via radio/phone ▪ Assist residents evacuate affected zones	▪ Trained civil servants and volunteers ▪ Usually organized around a school	▪ ~15 commit-tees ▪ 12-20 members each

SOURCE: INGC-CENOE

SLIDE 69



BEIRA

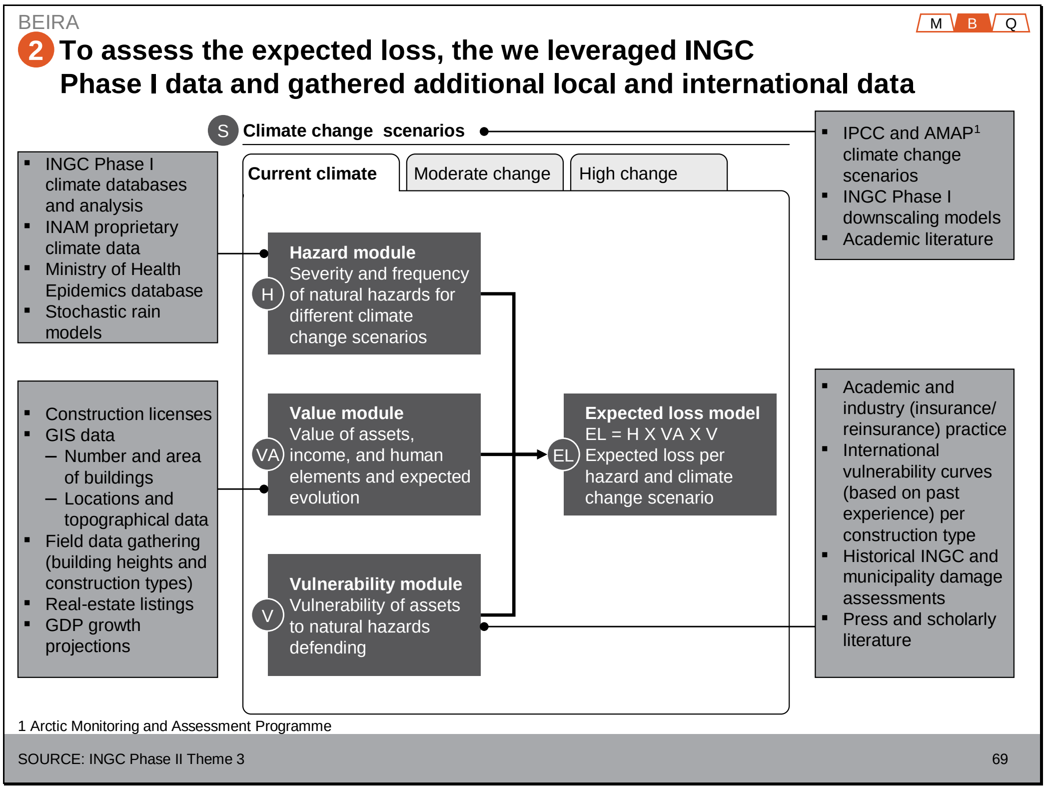
M B Q

1 C Beiras's disaster preparedness could be significantly increased by adding further emergency equipment and training officials

	Gap	Description	Plans for improvement
Resource needs	▪ Emergency kits for local committees	▪ Only one-third of local committees currently equipped with emergency kits	▪ None at present, aside from spontaneous NGO donations
	▪ Emergency equipment	▪ More vehicles, boats, tents, computers needed for adequate disaster response	▪ None at present
	▪ Communication equipment	▪ Radios, satellites, and training for technicians	▪ MSB (Sweden) funds to improve radio system ▪ DFID program for satellite capacity-building
Institutional capacity needs	▪ Training for government officials	▪ Training gap for city officials and traditional local authorities	▪ Red Cross currently training local committees
	▪ INGC capacity building	▪ Need for more trained technicians and incentives to retain them	▪ None at present

SOURCE: INGC; CENOE

SLIDE 70



BEIRA

M B Q

2 To assess the expected loss, the we leveraged INGC Phase I data and gathered additional local and international data

S **Climate change scenarios**

- INGC Phase I climate databases and analysis
- INAM proprietary climate data
- Ministry of Health Epidemics database
- Stochastic rain models

- Construction licenses
- GIS data
  - Number and area of buildings
  - Locations and topographical data
- Field data gathering (building heights and construction types)
- Real-estate listings
- GDP growth projections

Current climate | Moderate change | High change

H **Hazard module** Severity and frequency of natural hazards for different climate change scenarios

VA **Value module** Value of assets, income, and human elements and expected evolution

V **Vulnerability module** Vulnerability of assets to natural hazards defending

EL **Expected loss model** EL = H X VA X V Expected loss per hazard and climate change scenario

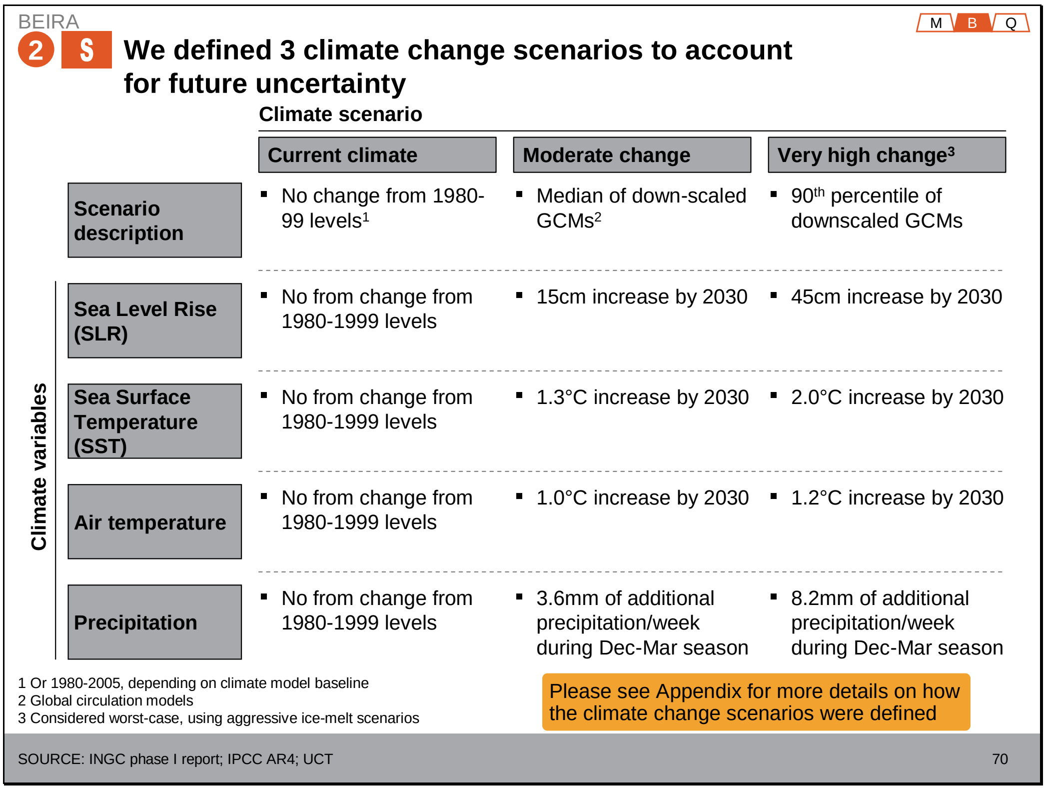
- IPCC and AMAP[1] climate change scenarios
- INGC Phase I downscaling models
- Academic literature

- Academic and industry (insurance/ reinsurance) practice
- International vulnerability curves (based on past experience) per construction type
- Historical INGC and municipality damage assessments
- Press and scholarly literature

[1] Arctic Monitoring and Assessment Programme

SOURCE: INGC Phase II Theme 3

SLIDE 71



BEIRA

M B Q

2 S We defined 3 climate change scenarios to account for future uncertainty

Climate scenario

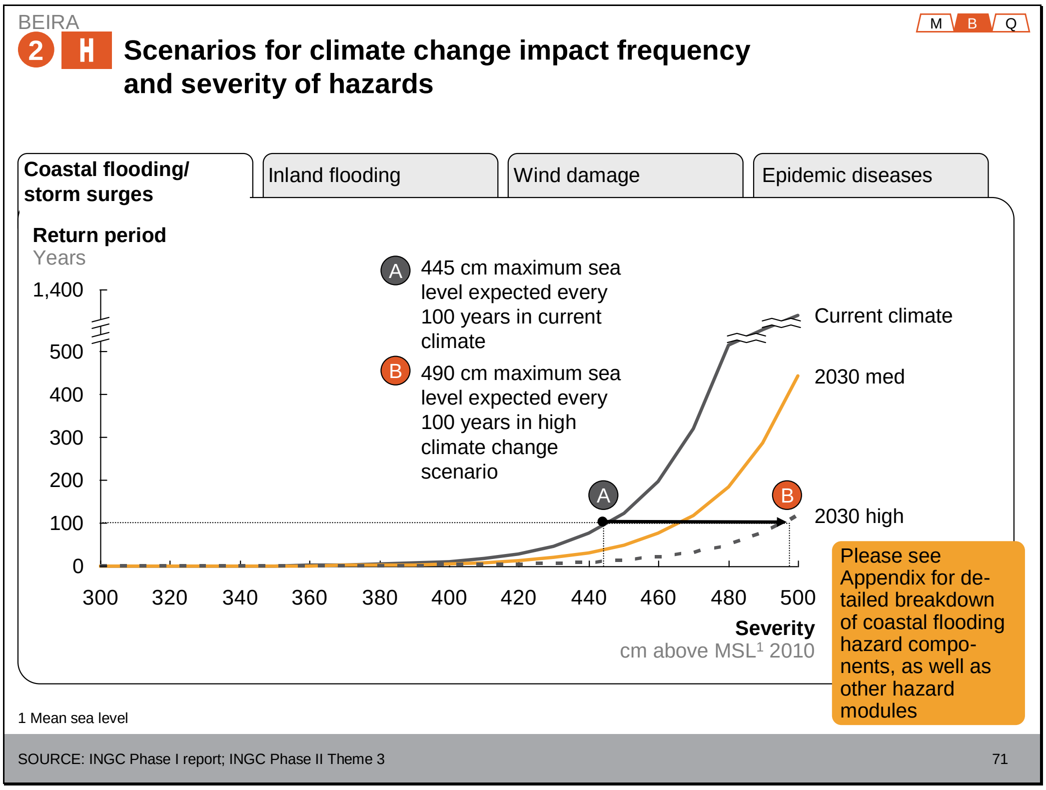
		Current climate	Moderate change	Very high change[3]
	Scenario description	No change from 1980-99 levels[1]	Median of down-scaled GCMs[2]	90th percentile of downscaled GCMs
Climate variables	**Sea Level Rise (SLR)**	No from change from 1980-1999 levels	15cm increase by 2030	45cm increase by 2030
	Sea Surface Temperature (SST)	No from change from 1980-1999 levels	1.3°C increase by 2030	2.0°C increase by 2030
	Air temperature	No from change from 1980-1999 levels	1.0°C increase by 2030	1.2°C increase by 2030
	Precipitation	No from change from 1980-1999 levels	3.6mm of additional precipitation/week during Dec-Mar season	8.2mm of additional precipitation/week during Dec-Mar season

[1] Or 1980-2005, depending on climate model baseline
[2] Global circulation models
[3] Considered worst-case, using aggressive ice-melt scenarios

Please see Appendix for more details on how the climate change scenarios were defined

SOURCE: INGC phase I report; IPCC AR4; UCT

SLIDE 72



BEIRA

2 H **Scenarios for climate change impact frequency and severity of hazards**

M B Q

Coastal flooding/ storm surges | Inland flooding | Wind damage | Epidemic diseases

Ⓐ 445 cm maximum sea level expected every 100 years in current climate

Ⓑ 490 cm maximum sea level expected every 100 years in high climate change scenario

Please see Appendix for detailed breakdown of coastal flooding hazard components, as well as other hazard modules

1 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II Theme 3

71

NOTES FOR SLIDE 72:

D1 – Magnitude of Expected Loss – Hazard Module – Coastal Flooding and Storm Surge

Scenarios for climate change impact frequency and severity of hazards.

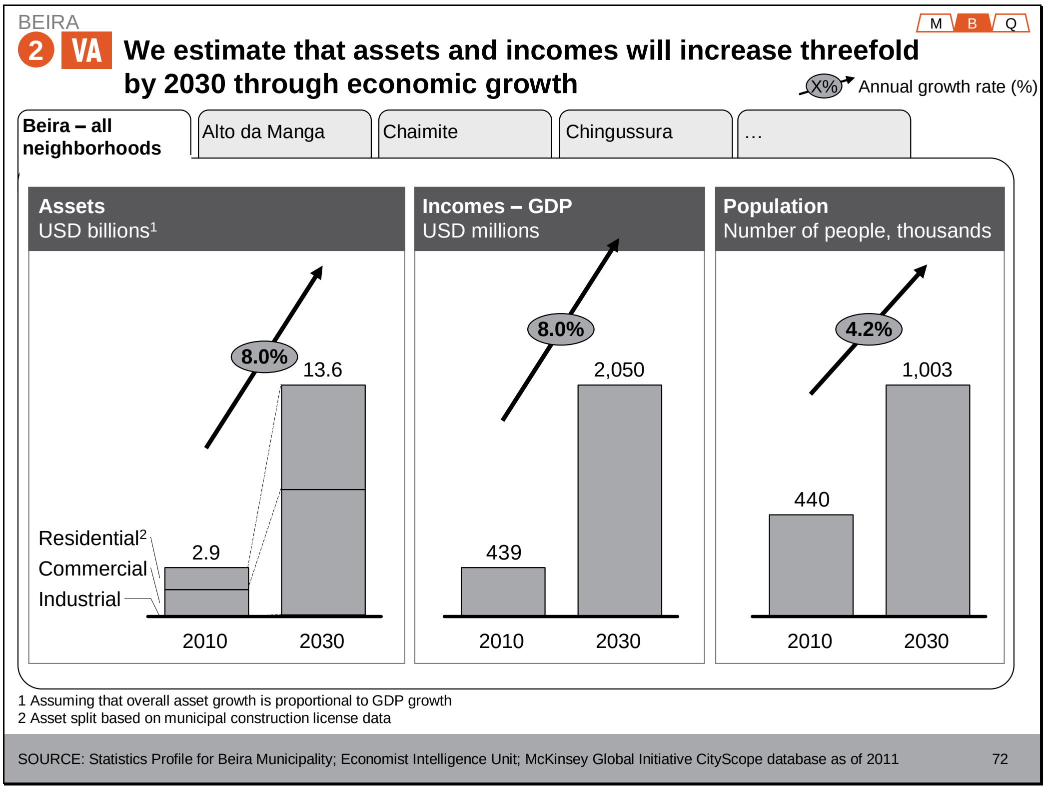
The frequency and severity of high level storm surges are compared for a number of different climate change scenarios for 2030.

The X axis charts the severity of the storm surge, meaning how many centimeters the 2010 Mean Sea Level the coastal waters will rise during a storm. The Y axis charts the "Return period", or frequency with which the event is likely to take place. The lines are the projections for the three modeled climate scenarios, a continuation of current climate, and a medium and high scenario.

Taken together, any point on one of these curves shows how often it is likely that storm surge will reach a particular level. A 100 year line is shown to indicate that that, if Current climate were to continue, a 445cm above MSL rise could be predicted once every hundred years.

The increasing severity of storm surges projected by 2030 is shown in the increasing cm rise projected every 100 years for the two more pessimistic climate scenario lines. For the 2030 medium climate change scenario, once in a 100 year storm surge increases to 490 cm above MSL, and 2030 high climate change will result in a significantly higher 100 year return storm surge.

SLIDE 73



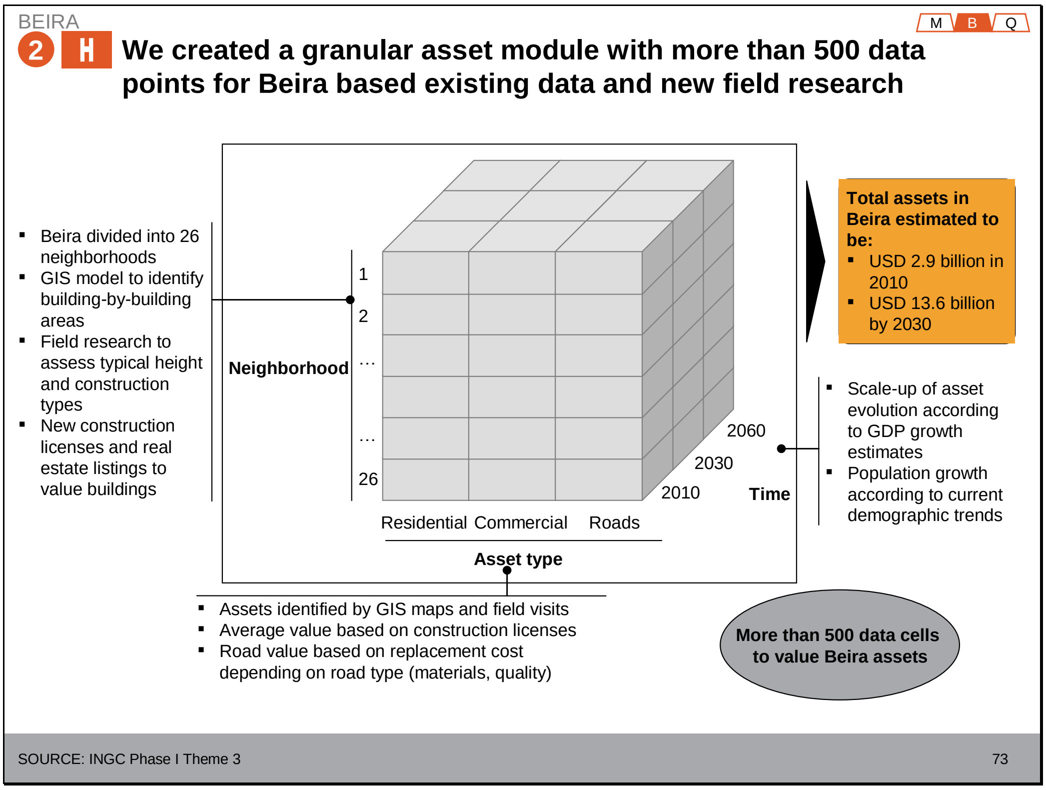
BEIRA

2 VA **We estimate that assets and incomes will increase threefold by 2030 through economic growth**

1 Assuming that overall asset growth is proportional to GDP growth
2 Asset split based on municipal construction license data

SOURCE: Statistics Profile for Beira Municipality; Economist Intelligence Unit; McKinsey Global Initiative CityScope database as of 2011

SLIDE 74



BEIRA

2 H **We created a granular asset module with more than 500 data points for Beira based existing data and new field research**

- Beira divided into 26 neighborhoods
- GIS model to identify building-by-building areas
- Field research to assess typical height and construction types
- New construction licenses and real estate listings to value buildings

Total assets in Beira estimated to be:
- USD 2.9 billion in 2010
- USD 13.6 billion by 2030

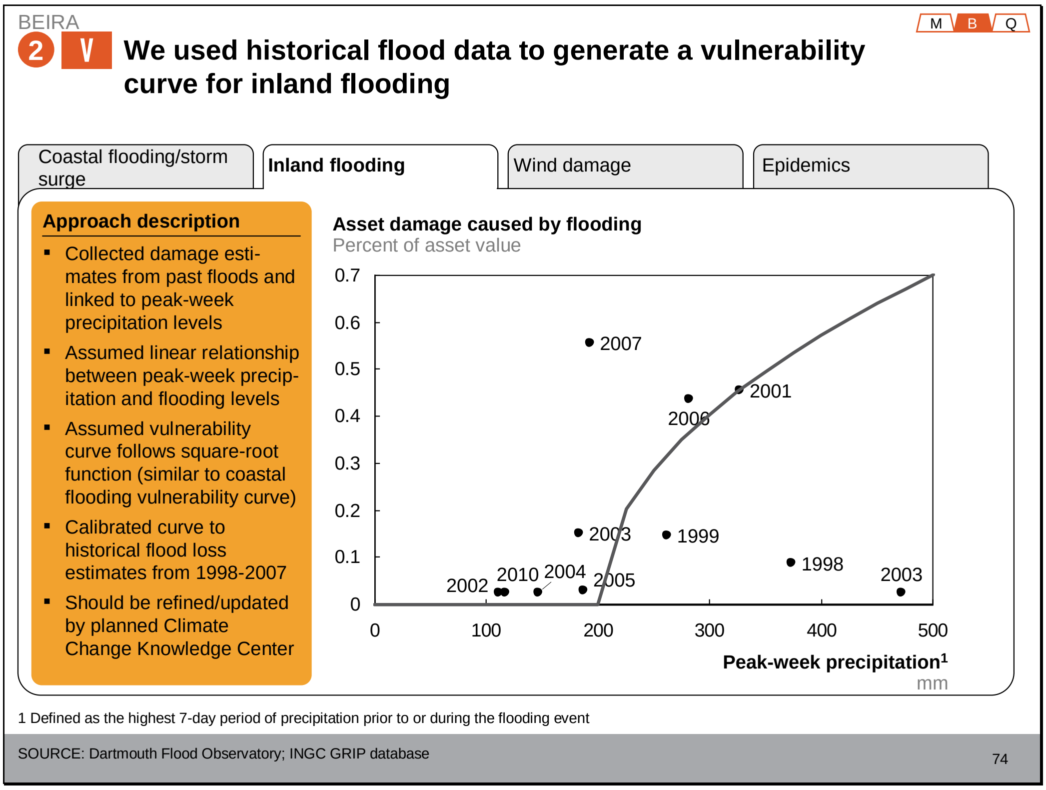
- Scale-up of asset evolution according to GDP growth estimates
- Population growth according to current demographic trends

- Assets identified by GIS maps and field visits
- Average value based on construction licenses
- Road value based on replacement cost depending on road type (materials, quality)

More than 500 data cells to value Beira assets

SOURCE: INGC Phase I Theme 3

SLIDE 75



BEIRA

We used historical flood data to generate a vulnerability curve for inland flooding

Approach description

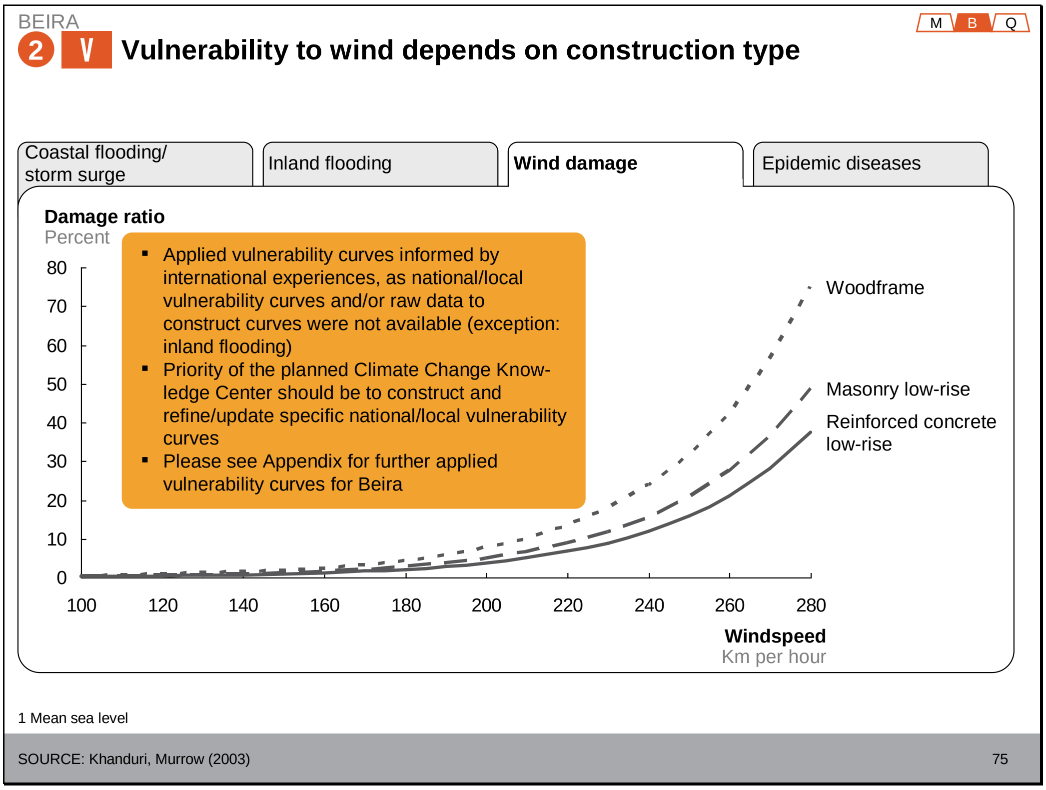
- Collected damage estimates from past floods and linked to peak-week precipitation levels
- Assumed linear relationship between peak-week precipitation and flooding levels
- Assumed vulnerability curve follows square-root function (similar to coastal flooding vulnerability curve)
- Calibrated curve to historical flood loss estimates from 1998-2007
- Should be refined/updated by planned Climate Change Knowledge Center

Asset damage caused by flooding
Percent of asset value

1 Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: Dartmouth Flood Observatory; INGC GRIP database

SLIDE 76



BEIRA

Vulnerability to wind depends on construction type

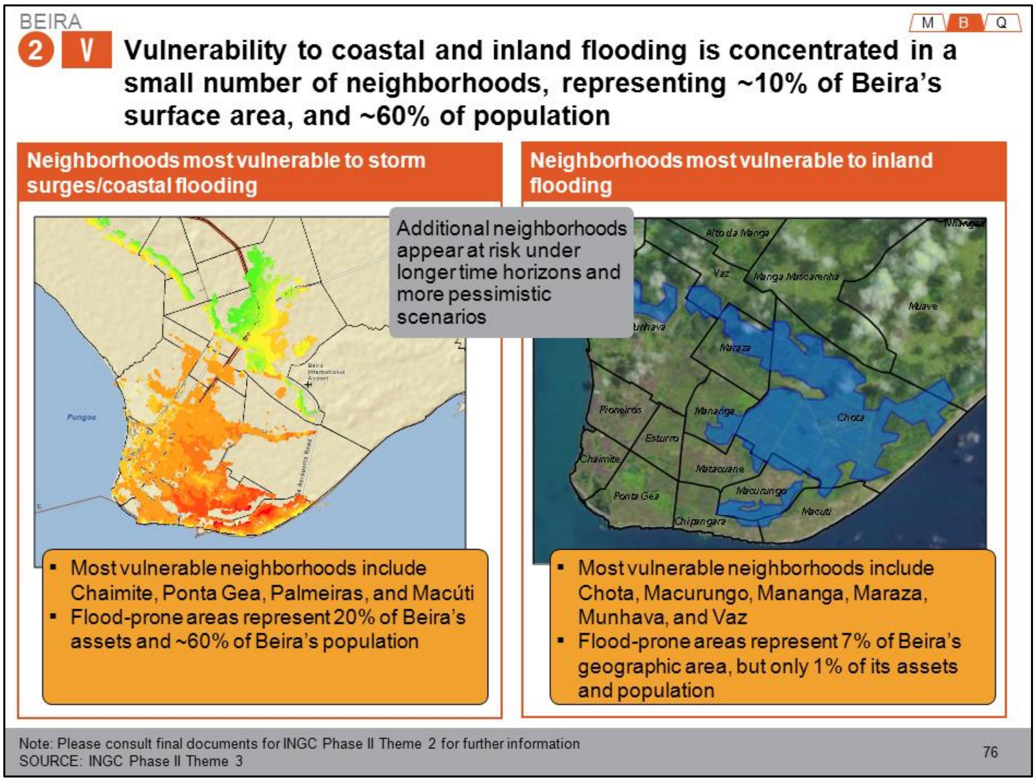
Damage ratio
Percent

- Applied vulnerability curves informed by international experiences, as national/local vulnerability curves and/or raw data to construct curves were not available (exception: inland flooding)
- Priority of the planned Climate Change Knowledge Center should be to construct and refine/update specific national/local vulnerability curves
- Please see Appendix for further applied vulnerability curves for Beira

1 Mean sea level

SOURCE: Khanduri, Murrow (2003)

SLIDE 77



BEIRA

2 **V** **Vulnerability to coastal and inland flooding is concentrated in a small number of neighborhoods, representing ~10% of Beira's surface area, and ~60% of population**

Neighborhoods most vulnerable to storm surges/coastal flooding

Additional neighborhoods appear at risk under longer time horizons and more pessimistic scenarios

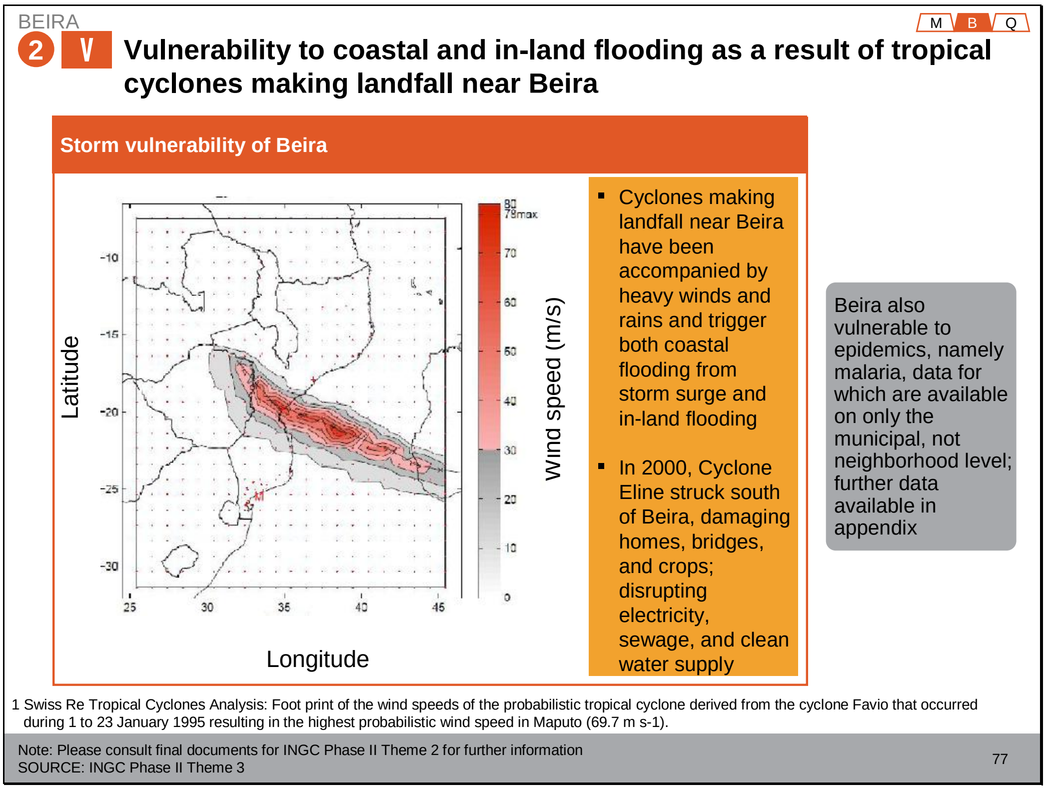
- Most vulnerable neighborhoods include Chaimite, Ponta Gea, Palmeiras, and Macúti
- Flood-prone areas represent 20% of Beira's assets and ~60% of Beira's population

Neighborhoods most vulnerable to inland flooding

- Most vulnerable neighborhoods include Chota, Macurungo, Mananga, Maraza, Munhava, and Vaz
- Flood-prone areas represent 7% of Beira's geographic area, but only 1% of its assets and population

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 78



BEIRA

2 **V** **Vulnerability to coastal and in-land flooding as a result of tropical cyclones making landfall near Beira**

Storm vulnerability of Beira

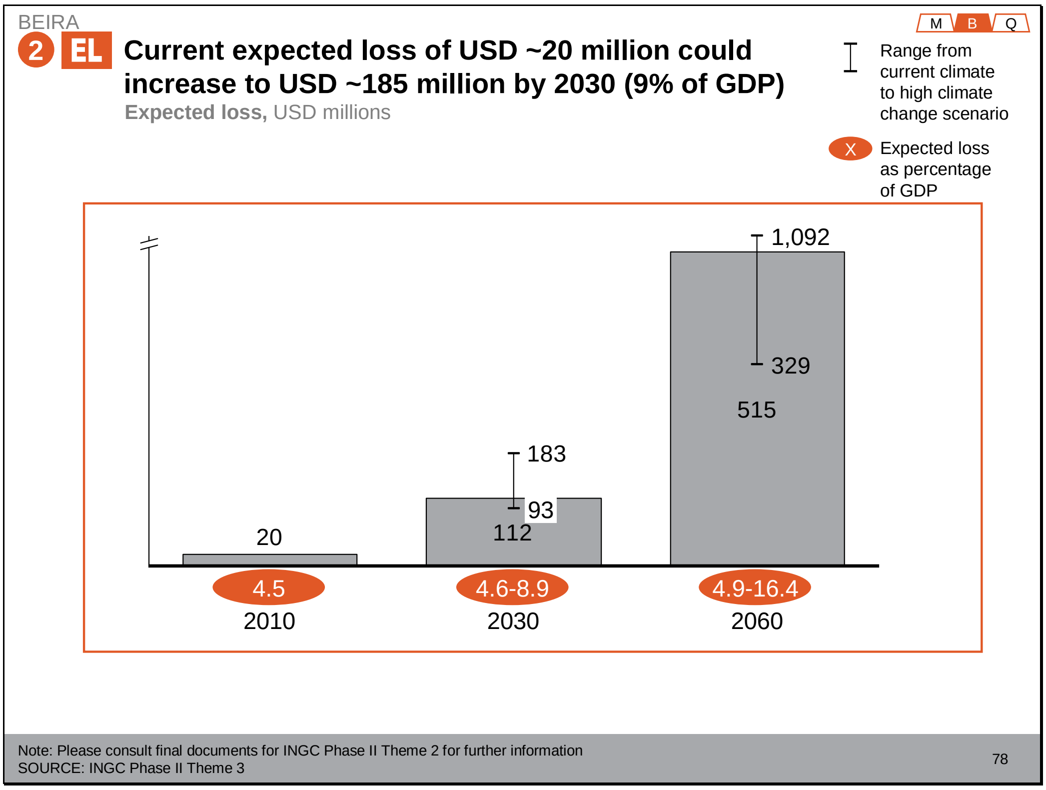
- Cyclones making landfall near Beira have been accompanied by heavy winds and rains and trigger both coastal flooding from storm surge and in-land flooding
- In 2000, Cyclone Eline struck south of Beira, damaging homes, bridges, and crops; disrupting electricity, sewage, and clean water supply

Beira also vulnerable to epidemics, namely malaria, data for which are available on only the municipal, not neighborhood level; further data available in appendix

1 Swiss Re Tropical Cyclones Analysis: Foot print of the wind speeds of the probabilistic tropical cyclone derived from the cyclone Favio that occurred during 1 to 23 January 1995 resulting in the highest probabilistic wind speed in Maputo (69.7 m s-1).

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 79



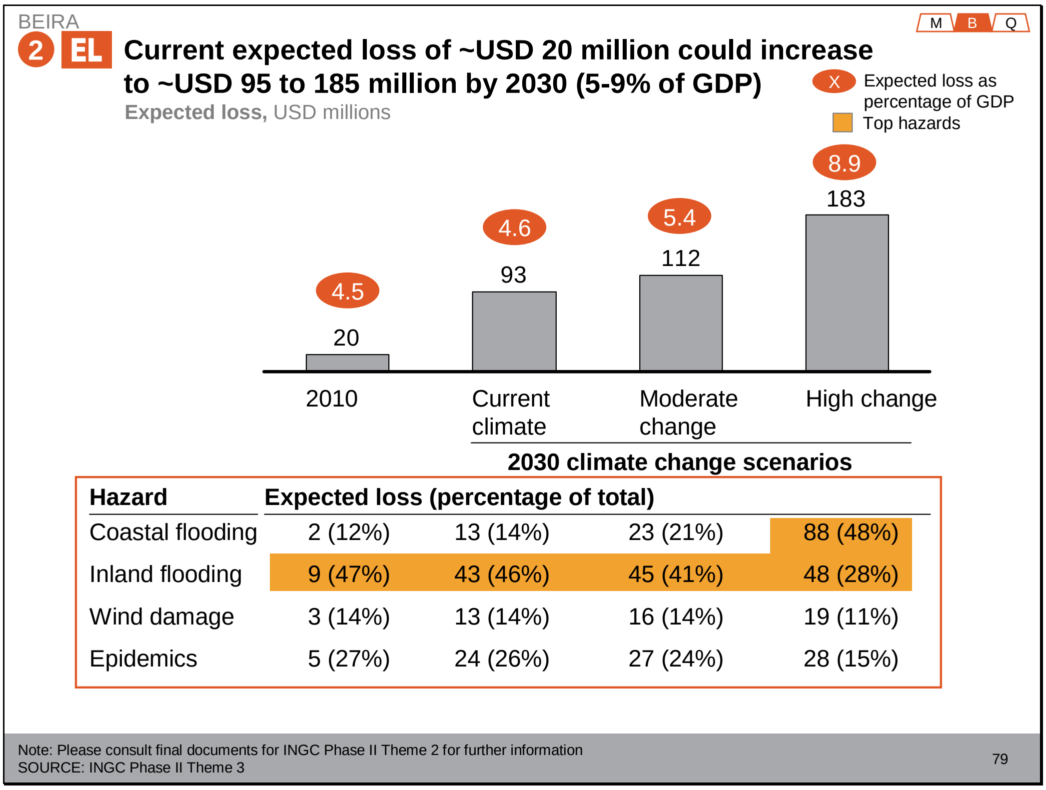
BEIRA

2 EL **Current expected loss of USD ~20 million could increase to USD ~185 million by 2030 (9% of GDP)**

Expected loss, USD millions

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 80



BEIRA

2 EL **Current expected loss of ~USD 20 million could increase to ~USD 95 to 185 million by 2030 (5-9% of GDP)**

Expected loss, USD millions

Hazard	Expected loss (percentage of total)			
Coastal flooding	2 (12%)	13 (14%)	23 (21%)	88 (48%)
Inland flooding	9 (47%)	43 (46%)	45 (41%)	48 (28%)
Wind damage	3 (14%)	13 (14%)	16 (14%)	19 (11%)
Epidemics	5 (27%)	24 (26%)	27 (24%)	28 (15%)

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 81

BEIRA

2 **EL**

Transport, housing, and medical services are those sectors mostly at risk from climate change effects

M B Q

Climate impact
○ Low
◑ Medium
● High

Sector	Risk from climate-related disasters	Rationale
Administration	○	▪ Main administrative buildings in safe areas
Transport	◑	▪ Coastal roads at risk of erosion; unpaved roads rendered impassable in heavy rains
Medical services	◑	▪ Some medical facilities surrounded by flood-prone access roads
Tourism	◑	▪ Some hotels and tourist facilities (especially new construction) vulnerable to coastal flooding
Business	◔	▪ Most businesses in safer, higher ground; port in lower-lying area, but protected by seawall
Houses and buildings	◕	▪ Risk from coastal and inland floods, especially new areas of development in Chota and Macarungo

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

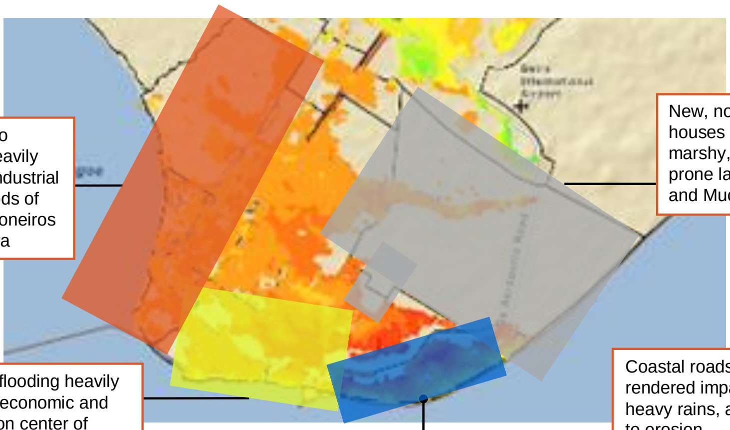
SLIDE 82

BEIRA

2 **EL**

Much of the rapid new development in Beira in these sectors is in flood-prone areas

M B Q



Flooding also impacting heavily developed industrial neighborhoods of Chaimite, Pioneiros and Munhava

New, not-to-code houses being built on marshy, inland flood-prone land in Chota and Mucurungo

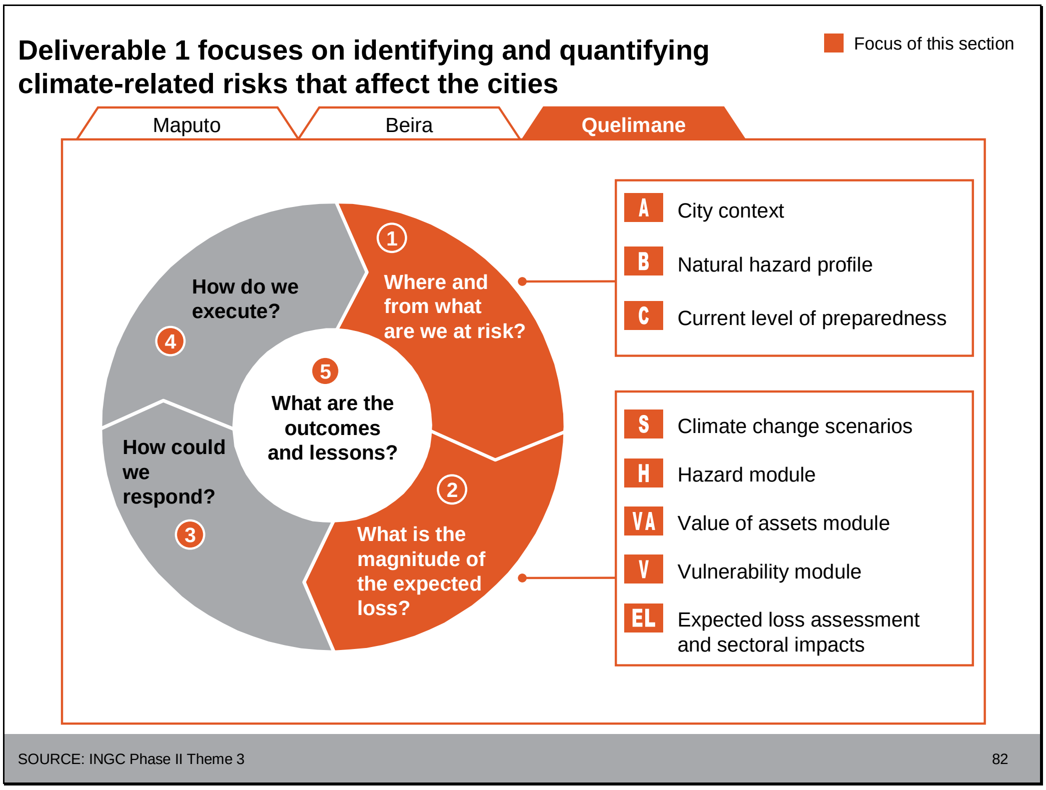
Coastal flooding heavily impacts economic and population center of Beira, defined by Ponta Gea, Macuti, and Mananga

Commercial development of hotels, condos, and restaurants, etc. very near flood-prone shore in Macuti

Coastal roads frequently rendered impassible in heavy rains, and prone to erosion

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 83



Deliverable 1 focuses on identifying and quantifying climate-related risks that affect the cities

🟧 Focus of this section

Maputo | Beira | **Quelimane**

① Where and from what are we at risk?

② What is the magnitude of the expected loss?

③ How could we respond?

④ How do we execute?

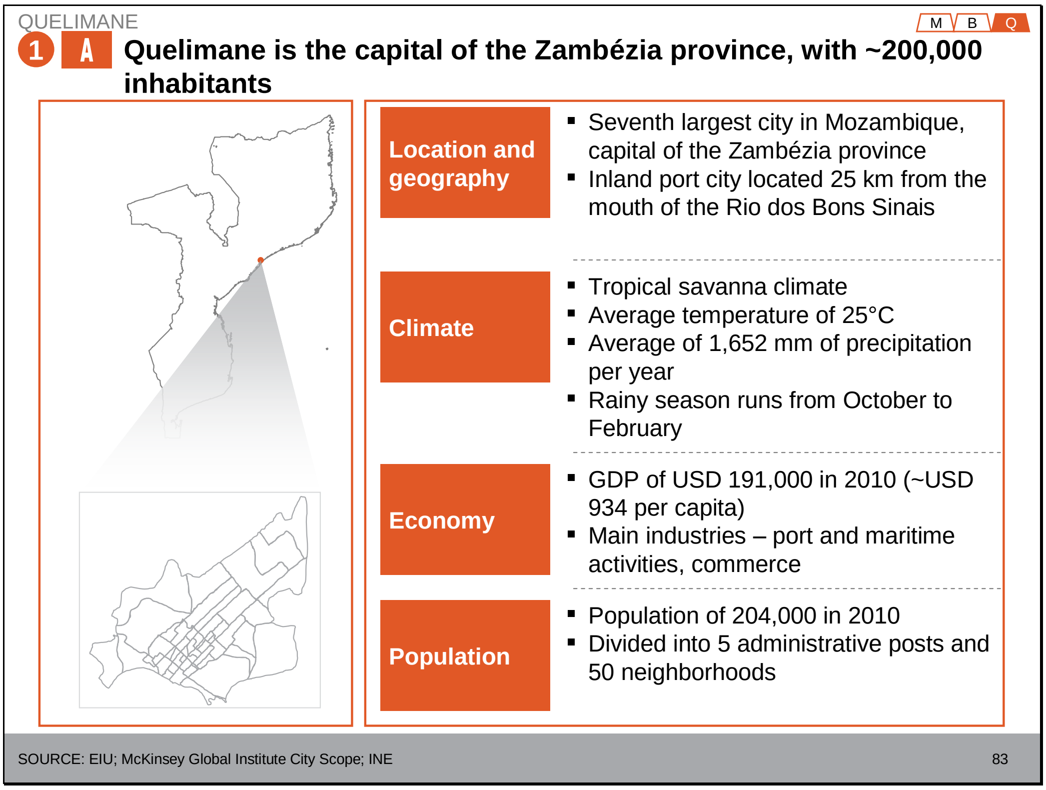
⑤ What are the outcomes and lessons?

A	City context
B	Natural hazard profile
C	Current level of preparedness

S	Climate change scenarios
H	Hazard module
VA	Value of assets module
V	Vulnerability module
EL	Expected loss assessment and sectoral impacts

SOURCE: INGC Phase II Theme 3

SLIDE 84



QUELIMANE

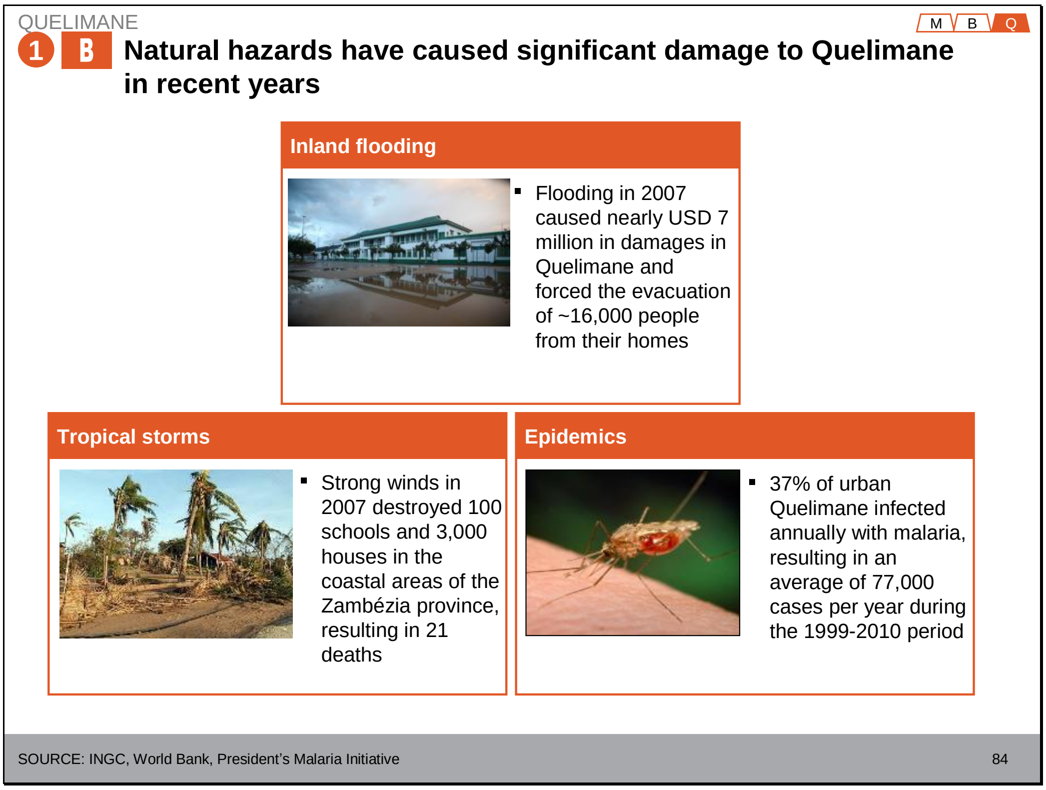
M | B | **Q**

① A Quelimane is the capital of the Zambézia province, with ~200,000 inhabitants

Location and geography	▪ Seventh largest city in Mozambique, capital of the Zambézia province ▪ Inland port city located 25 km from the mouth of the Rio dos Bons Sinais
Climate	▪ Tropical savanna climate ▪ Average temperature of 25°C ▪ Average of 1,652 mm of precipitation per year ▪ Rainy season runs from October to February
Economy	▪ GDP of USD 191,000 in 2010 (~USD 934 per capita) ▪ Main industries – port and maritime activities, commerce
Population	▪ Population of 204,000 in 2010 ▪ Divided into 5 administrative posts and 50 neighborhoods

SOURCE: EIU; McKinsey Global Institute City Scope; INE

SLIDE 85



QUELIMANE

1 B **Natural hazards have caused significant damage to Quelimane in recent years**

Inland flooding

- Flooding in 2007 caused nearly USD 7 million in damages in Quelimane and forced the evacuation of ~16,000 people from their homes

Tropical storms

- Strong winds in 2007 destroyed 100 schools and 3,000 houses in the coastal areas of the Zambézia province, resulting in 21 deaths

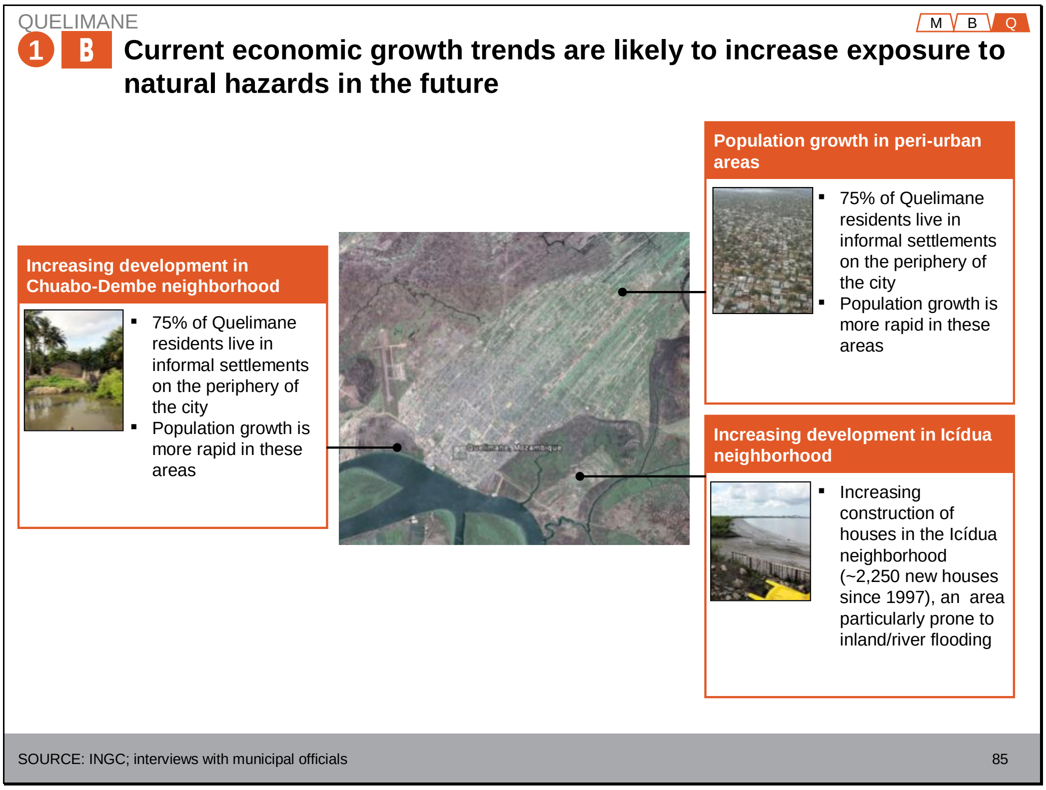
Epidemics

- 37% of urban Quelimane infected annually with malaria, resulting in an average of 77,000 cases per year during the 1999-2010 period

SOURCE: INGC, World Bank, President's Malaria Initiative

84

SLIDE 86



QUELIMANE

1 B **Current economic growth trends are likely to increase exposure to natural hazards in the future**

Increasing development in Chuabo-Dembe neighborhood

- 75% of Quelimane residents live in informal settlements on the periphery of the city
- Population growth is more rapid in these areas

Population growth in peri-urban areas

- 75% of Quelimane residents live in informal settlements on the periphery of the city
- Population growth is more rapid in these areas

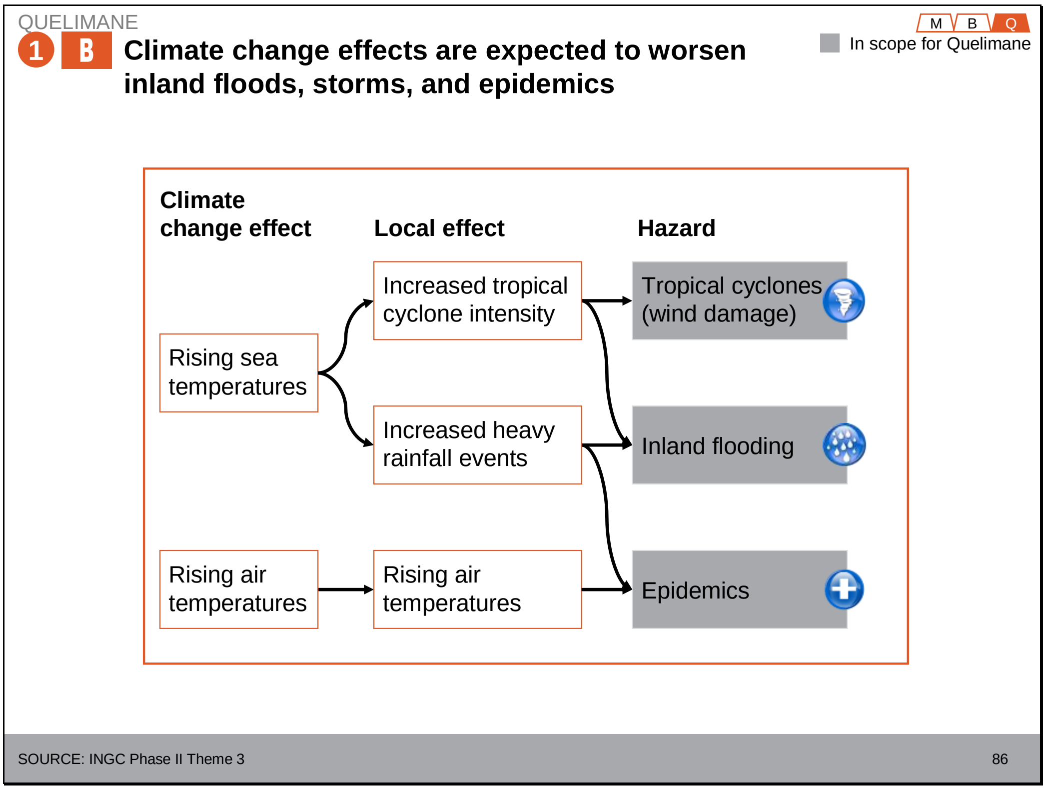
Increasing development in Icídua neighborhood

- Increasing construction of houses in the Icídua neighborhood (~2,250 new houses since 1997), an area particularly prone to inland/river flooding

SOURCE: INGC; interviews with municipal officials

85

SLIDE 87



QUELIMANE

M B Q

▨ In scope for Quelimane

1 B Climate change effects are expected to worsen inland floods, storms, and epidemics

Climate change effect | **Local effect** | **Hazard**

Rising sea temperatures → Increased tropical cyclone intensity → Tropical cyclones (wind damage)

Rising sea temperatures → Increased heavy rainfall events → Inland flooding

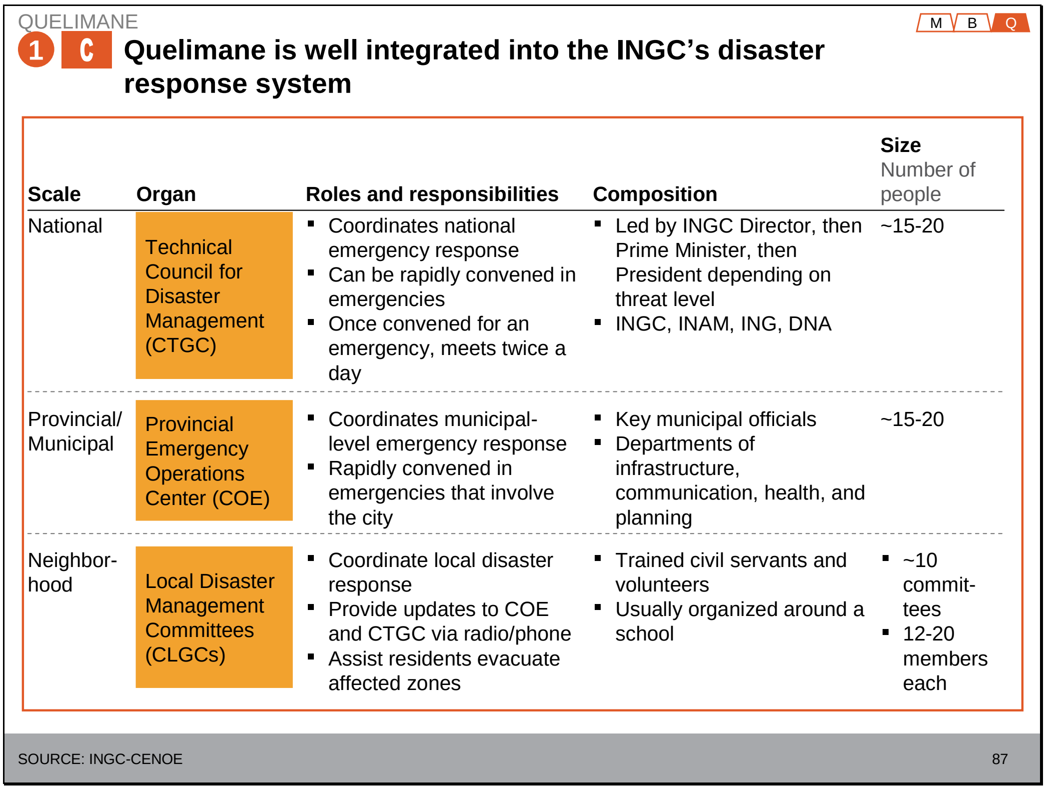
Increased tropical cyclone intensity → Inland flooding

Increased heavy rainfall events → Epidemics

Rising air temperatures → Rising air temperatures → Epidemics

SOURCE: INGC Phase II Theme 3

SLIDE 88



QUELIMANE

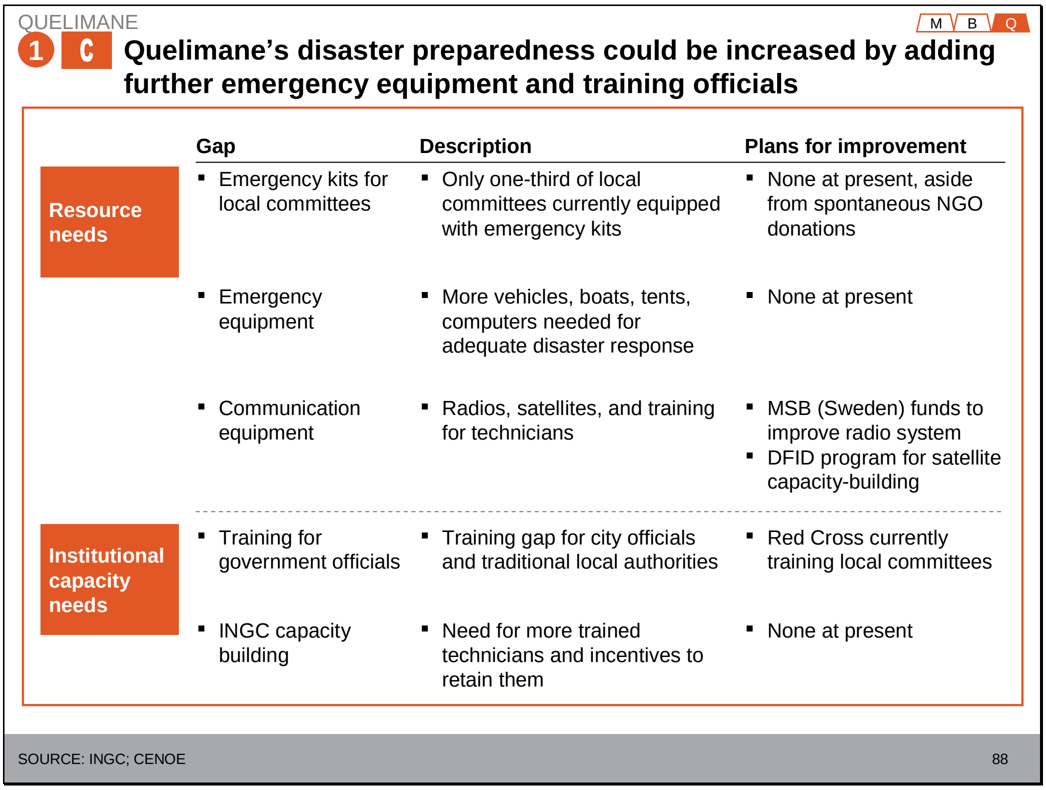
M B Q

1 C Quelimane is well integrated into the INGC's disaster response system

Scale	Organ	Roles and responsibilities	Composition	**Size** Number of people
National	Technical Council for Disaster Management (CTGC)	▪ Coordinates national emergency response ▪ Can be rapidly convened in emergencies ▪ Once convened for an emergency, meets twice a day	▪ Led by INGC Director, then Prime Minister, then President depending on threat level ▪ INGC, INAM, ING, DNA	~15-20
Provincial/ Municipal	Provincial Emergency Operations Center (COE)	▪ Coordinates municipal-level emergency response ▪ Rapidly convened in emergencies that involve the city	▪ Key municipal officials ▪ Departments of infrastructure, communication, health, and planning	~15-20
Neighbor-hood	Local Disaster Management Committees (CLGCs)	▪ Coordinate local disaster response ▪ Provide updates to COE and CTGC via radio/phone ▪ Assist residents evacuate affected zones	▪ Trained civil servants and volunteers ▪ Usually organized around a school	▪ ~10 commit-tees ▪ 12-20 members each

SOURCE: INGC-CENOE

SLIDE 89



QUELIMANE

M B Q

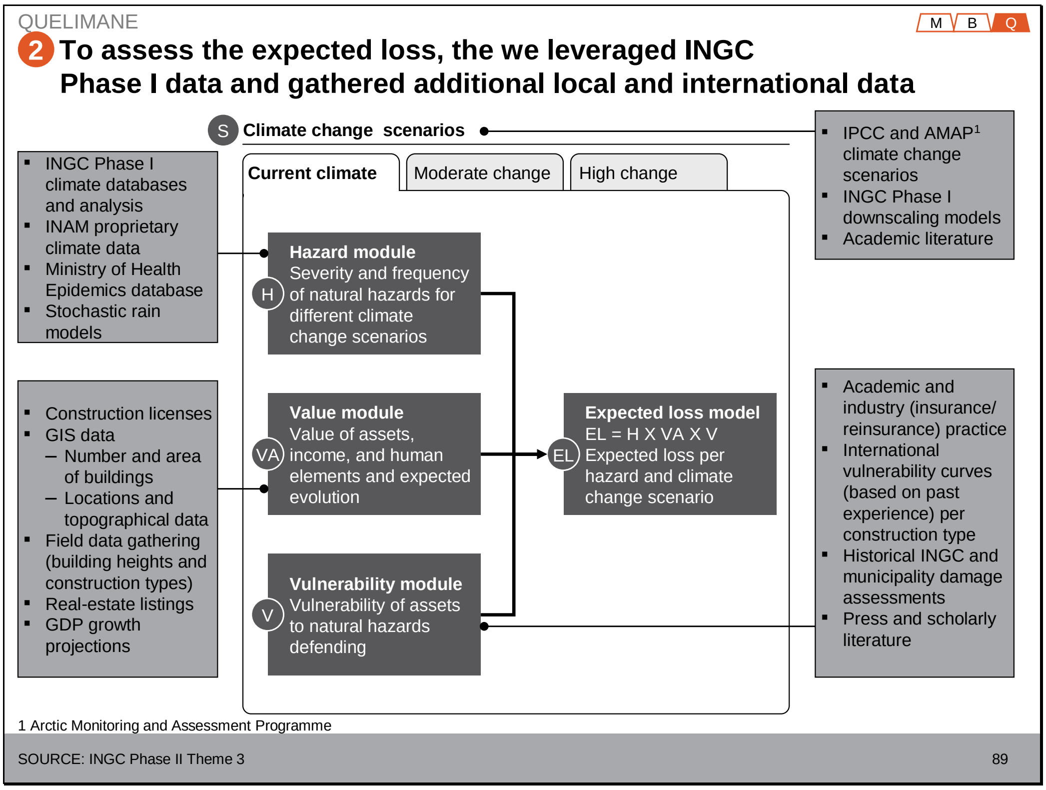
1 C Quelimane's disaster preparedness could be increased by adding further emergency equipment and training officials

	Gap	Description	Plans for improvement
Resource needs	Emergency kits for local committees	Only one-third of local committees currently equipped with emergency kits	None at present, aside from spontaneous NGO donations
	Emergency equipment	More vehicles, boats, tents, computers needed for adequate disaster response	None at present
	Communication equipment	Radios, satellites, and training for technicians	MSB (Sweden) funds to improve radio system DFID program for satellite capacity-building
Institutional capacity needs	Training for government officials	Training gap for city officials and traditional local authorities	Red Cross currently training local committees
	INGC capacity building	Need for more trained technicians and incentives to retain them	None at present

SOURCE: INGC; CENOE

88

SLIDE 90



QUELIMANE

M B Q

2 To assess the expected loss, the we leveraged INGC Phase I data and gathered additional local and international data

S **Climate change scenarios**

Current climate | Moderate change | High change

- INGC Phase I climate databases and analysis
- INAM proprietary climate data
- Ministry of Health Epidemics database
- Stochastic rain models

- Construction licenses
- GIS data
  - Number and area of buildings
  - Locations and topographical data
- Field data gathering (building heights and construction types)
- Real-estate listings
- GDP growth projections

H **Hazard module**
Severity and frequency of natural hazards for different climate change scenarios

VA **Value module**
Value of assets, income, and human elements and expected evolution

V **Vulnerability module**
Vulnerability of assets to natural hazards defending

EL **Expected loss model**
EL = H X VA X V
Expected loss per hazard and climate change scenario

- IPCC and AMAP[1] climate change scenarios
- INGC Phase I downscaling models
- Academic literature

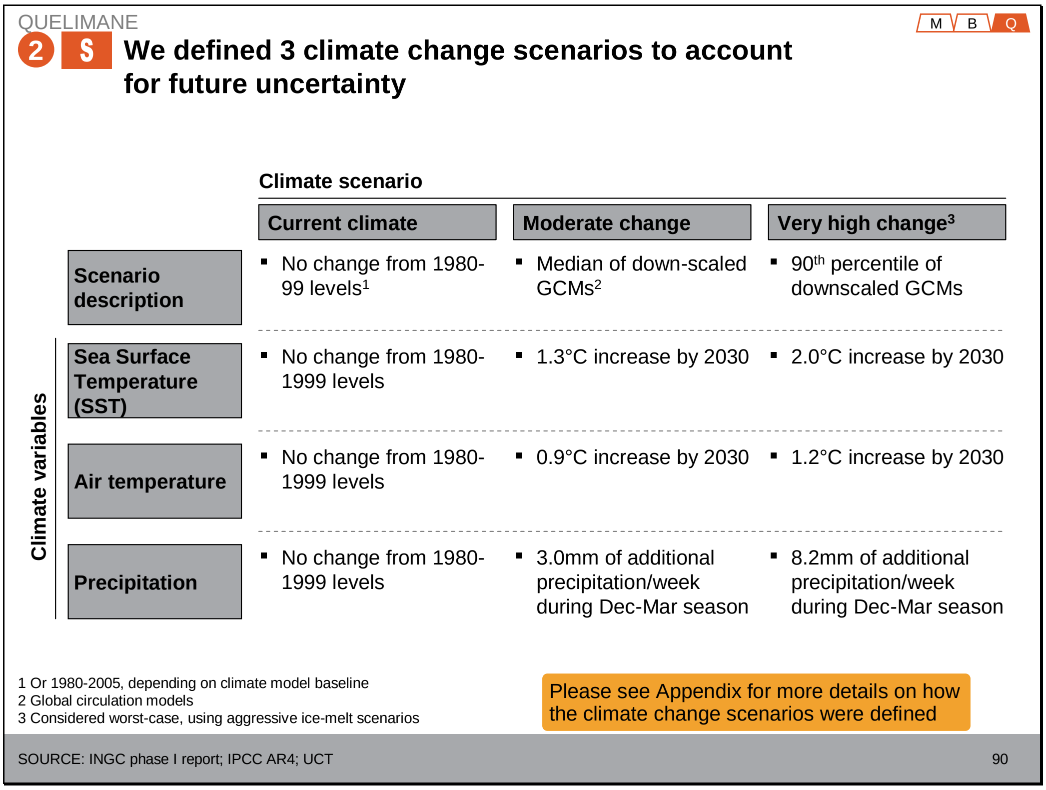
- Academic and industry (insurance/ reinsurance) practice
- International vulnerability curves (based on past experience) per construction type
- Historical INGC and municipality damage assessments
- Press and scholarly literature

1 Arctic Monitoring and Assessment Programme

SOURCE: INGC Phase II Theme 3

89

SLIDE 91



QUELIMANE

M B Q

2 S We defined 3 climate change scenarios to account for future uncertainty

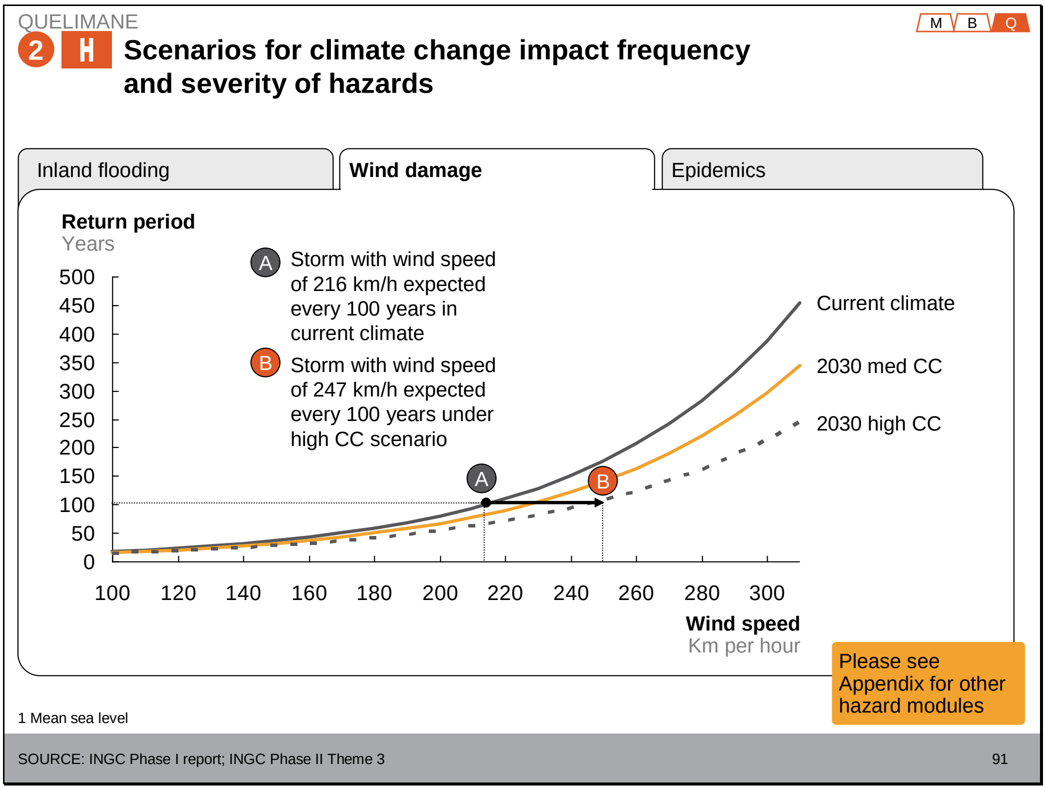
		Climate scenario		
		Current climate	**Moderate change**	**Very high change[3]**
	Scenario description	▪ No change from 1980-99 levels[1]	▪ Median of down-scaled GCMs[2]	▪ 90th percentile of downscaled GCMs
Climate variables	**Sea Surface Temperature (SST)**	▪ No change from 1980-1999 levels	▪ 1.3°C increase by 2030	▪ 2.0°C increase by 2030
	Air temperature	▪ No change from 1980-1999 levels	▪ 0.9°C increase by 2030	▪ 1.2°C increase by 2030
	Precipitation	▪ No change from 1980-1999 levels	▪ 3.0mm of additional precipitation/week during Dec-Mar season	▪ 8.2mm of additional precipitation/week during Dec-Mar season

1 Or 1980-2005, depending on climate model baseline
2 Global circulation models
3 Considered worst-case, using aggressive ice-melt scenarios

Please see Appendix for more details on how the climate change scenarios were defined

SOURCE: INGC phase I report; IPCC AR4; UCT

SLIDE 92



QUELIMANE

M B Q

2 H Scenarios for climate change impact frequency and severity of hazards

Inland flooding | **Wind damage** | Epidemics

Ⓐ Storm with wind speed of 216 km/h expected every 100 years in current climate

Ⓑ Storm with wind speed of 247 km/h expected every 100 years under high CC scenario

Please see Appendix for other hazard modules

1 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II Theme 3

NOTES FOR SLIDE 92:

D1 – Magnitude of Expected Loss – Hazard Module – Wind damage

Scenarios for climate change impact frequency and severity of hazards.

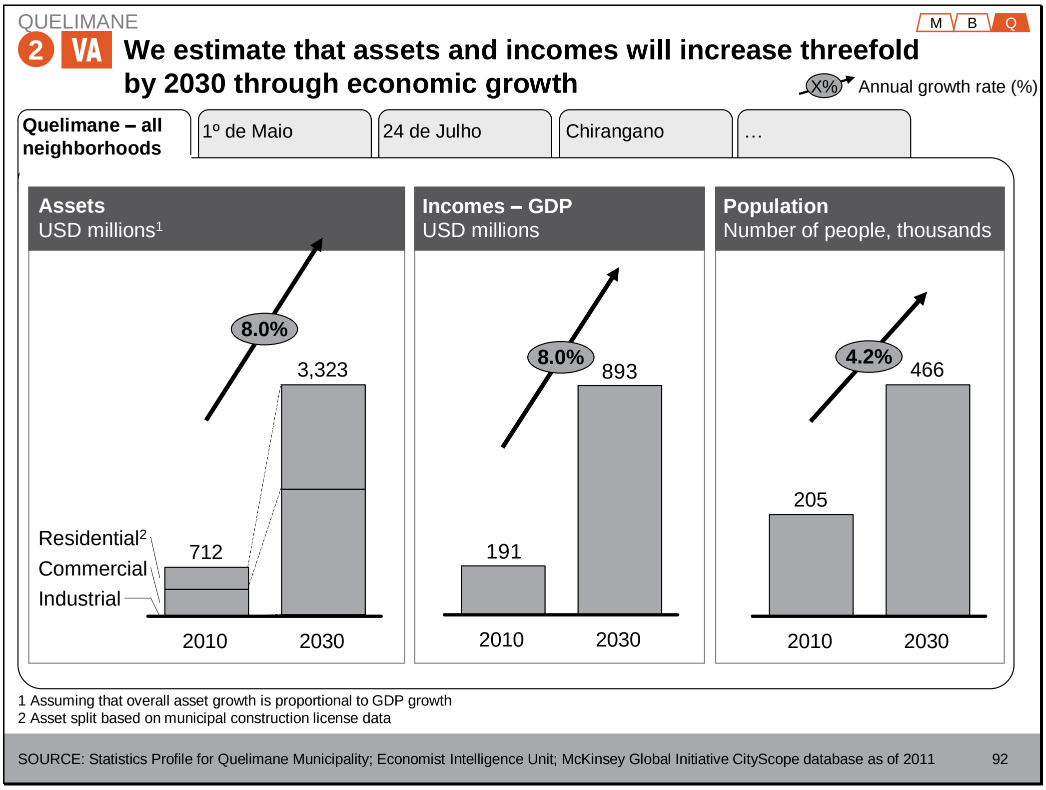
The frequency and severity of high wind speeds are compared for three different climate change scenarios for 2030.

The X axis charts the severity of the wind speed in Km per hour. The Y axis charts the "Return period", or frequency with which the event is likely to take place. The lines are the projections for the three modeled climate scenarios, a continuation of current climate, and medium and high scenarios.

Taken together, any point on one of these curves shows how often it is likely that wind speeds will reach a particular level. A 100 year line is shown to indicate that that, if current climate were to continue, a 216 km/h wind speed could be predicted once every hundred years.

The increasing severity of wind speeds projected by 2030 is shown in the increasing speeds projected every 100 years for the two more pessimistic climate scenario lines. For the 2030 high climate change scenario, for example, once in a 100 year wind speed increases to 247 Km/hour.

SLIDE 93



QUELIMANE

M B Q

2 VA **We estimate that assets and incomes will increase threefold by 2030 through economic growth**

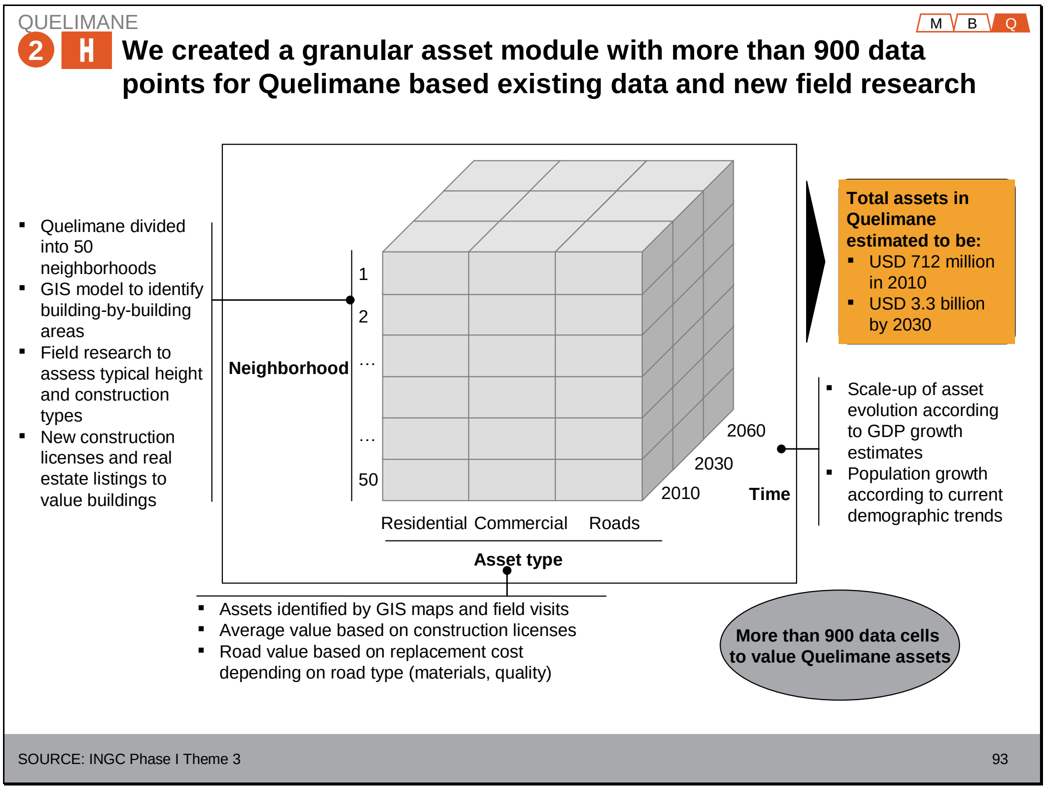
X% Annual growth rate (%)

Quelimane – all neighborhoods | 1º de Maio | 24 de Julho | Chirangano | …

1 Assuming that overall asset growth is proportional to GDP growth
2 Asset split based on municipal construction license data

SOURCE: Statistics Profile for Quelimane Municipality; Economist Intelligence Unit; McKinsey Global Initiative CityScope database as of 2011

SLIDE 94



QUELIMANE

M B Q

2 H We created a granular asset module with more than 900 data points for Quelimane based existing data and new field research

- Quelimane divided into 50 neighborhoods
- GIS model to identify building-by-building areas
- Field research to assess typical height and construction types
- New construction licenses and real estate listings to value buildings

Total assets in Quelimane estimated to be:
- USD 712 million in 2010
- USD 3.3 billion by 2030

- Scale-up of asset evolution according to GDP growth estimates
- Population growth according to current demographic trends

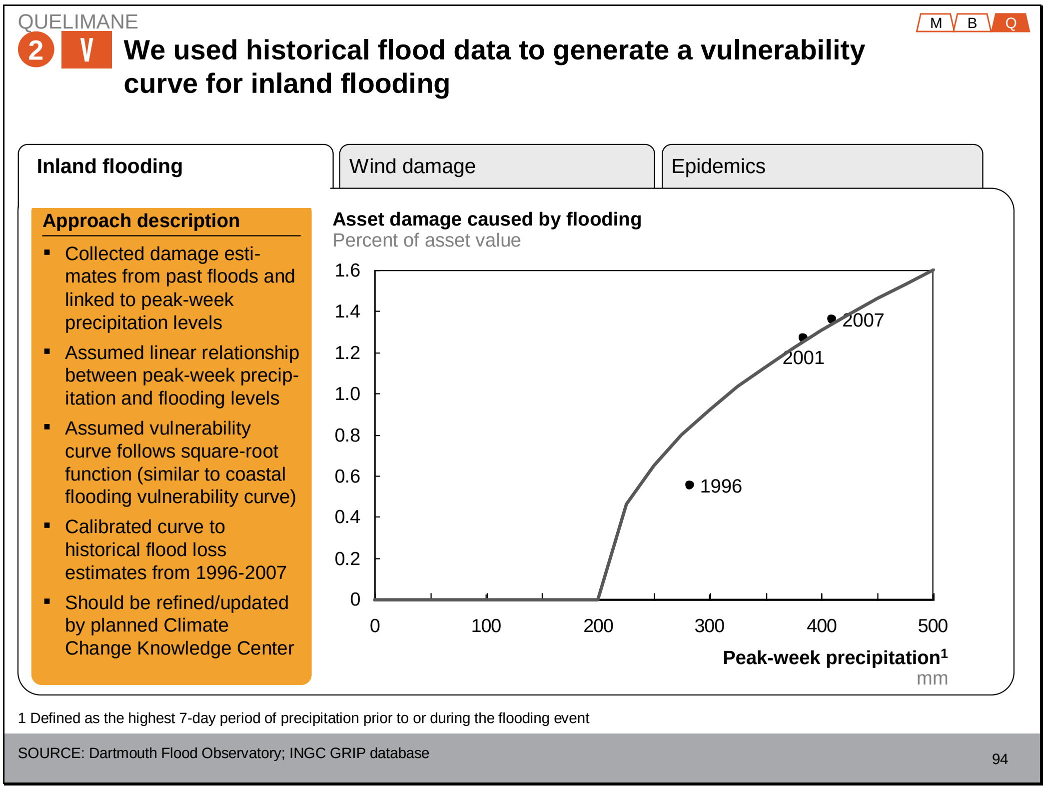
- Assets identified by GIS maps and field visits
- Average value based on construction licenses
- Road value based on replacement cost depending on road type (materials, quality)

More than 900 data cells to value Quelimane assets

SOURCE: INGC Phase I Theme 3

93

SLIDE 95



QUELIMANE

M B Q

2 V We used historical flood data to generate a vulnerability curve for inland flooding

Inland flooding | Wind damage | Epidemics

Approach description
- Collected damage estimates from past floods and linked to peak-week precipitation levels
- Assumed linear relationship between peak-week precipitation and flooding levels
- Assumed vulnerability curve follows square-root function (similar to coastal flooding vulnerability curve)
- Calibrated curve to historical flood loss estimates from 1996-2007
- Should be refined/updated by planned Climate Change Knowledge Center

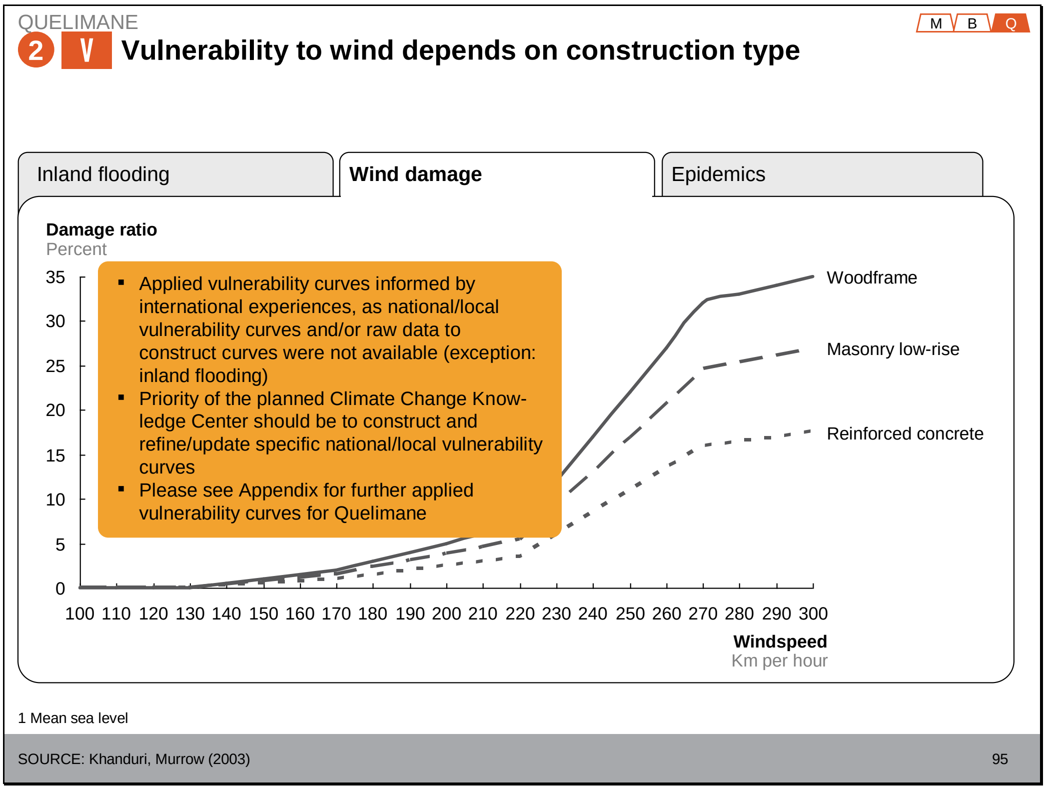
Asset damage caused by flooding
Percent of asset value

1 Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: Dartmouth Flood Observatory; INGC GRIP database

94

SLIDE 96



QUELIMANE

M B Q

2 V Vulnerability to wind depends on construction type

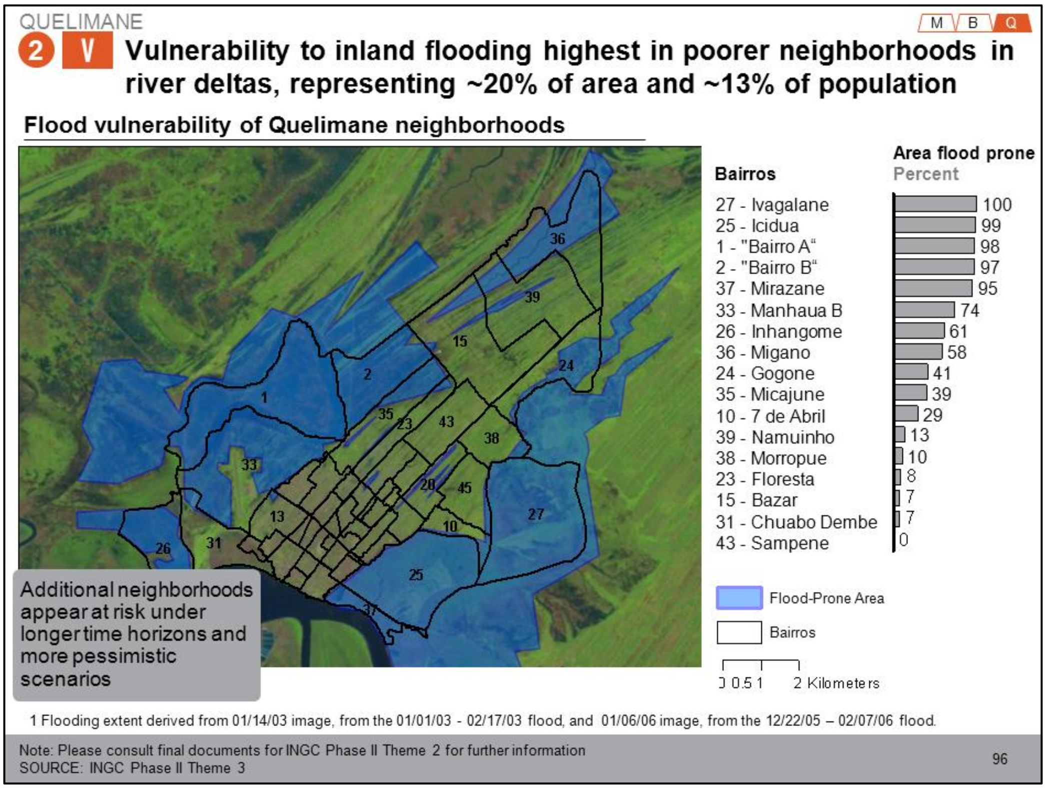
Inland flooding | **Wind damage** | Epidemics

- Applied vulnerability curves informed by international experiences, as national/local vulnerability curves and/or raw data to construct curves were not available (exception: inland flooding)
- Priority of the planned Climate Change Knowledge Center should be to construct and refine/update specific national/local vulnerability curves
- Please see Appendix for further applied vulnerability curves for Quelimane

1 Mean sea level

SOURCE: Khanduri, Murrow (2003)

SLIDE 97



QUELIMANE

M B Q

2 V Vulnerability to inland flooding highest in poorer neighborhoods in river deltas, representing ~20% of area and ~13% of population

Flood vulnerability of Quelimane neighborhoods

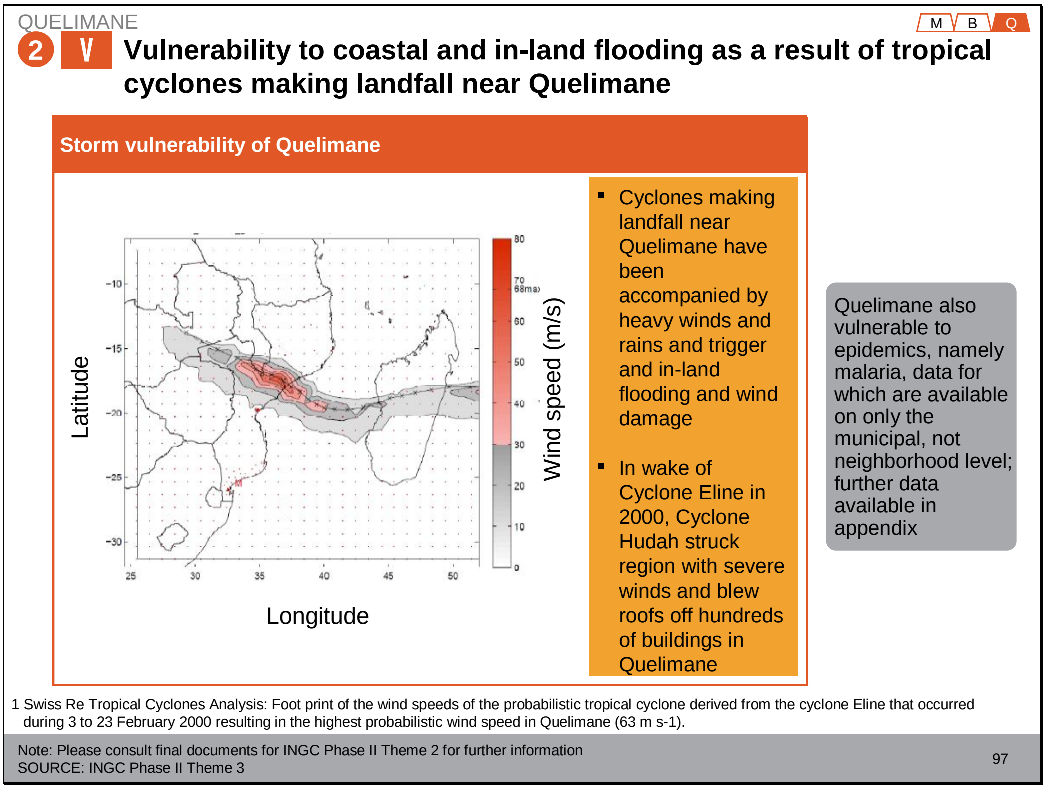
Bairros	**Area flood prone** Percent
27 - Ivagalane	100
25 - Icidua	99
1 - "Bairro A"	98
2 - "Bairro B"	97
37 - Mirazane	95
33 - Manhaua B	74
26 - Inhangome	61
36 - Migano	58
24 - Gogone	41
35 - Micajune	39
10 - 7 de Abril	29
39 - Namuinho	13
38 - Morropue	10
23 - Floresta	8
15 - Bazar	7
31 - Chuabo Dembe	7
43 - Sampene	0

Additional neighborhoods appear at risk under longer time horizons and more pessimistic scenarios

1 Flooding extent derived from 01/14/03 image, from the 01/01/03 - 02/17/03 flood, and 01/06/06 image, from the 12/22/05 – 02/07/06 flood.

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 98



QUELIMANE

M B Q

2 V Vulnerability to coastal and in-land flooding as a result of tropical cyclones making landfall near Quelimane

Storm vulnerability of Quelimane

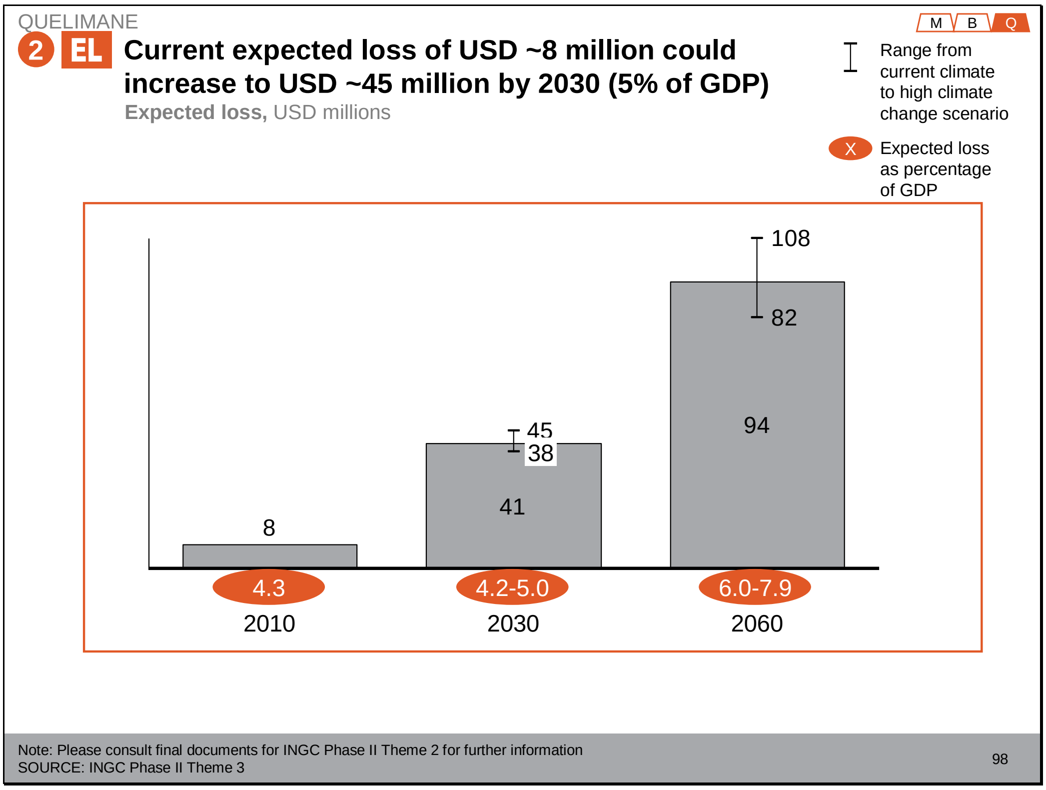
- Cyclones making landfall near Quelimane have been accompanied by heavy winds and rains and trigger and in-land flooding and wind damage
- In wake of Cyclone Eline in 2000, Cyclone Hudah struck region with severe winds and blew roofs off hundreds of buildings in Quelimane

Quelimane also vulnerable to epidemics, namely malaria, data for which are available on only the municipal, not neighborhood level; further data available in appendix

1 Swiss Re Tropical Cyclones Analysis: Foot print of the wind speeds of the probabilistic tropical cyclone derived from the cyclone Eline that occurred during 3 to 23 February 2000 resulting in the highest probabilistic wind speed in Quelimane (63 m s-1).

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 99



QUELIMANE

M B Q

2 EL Current expected loss of USD ~8 million could increase to USD ~45 million by 2030 (5% of GDP)

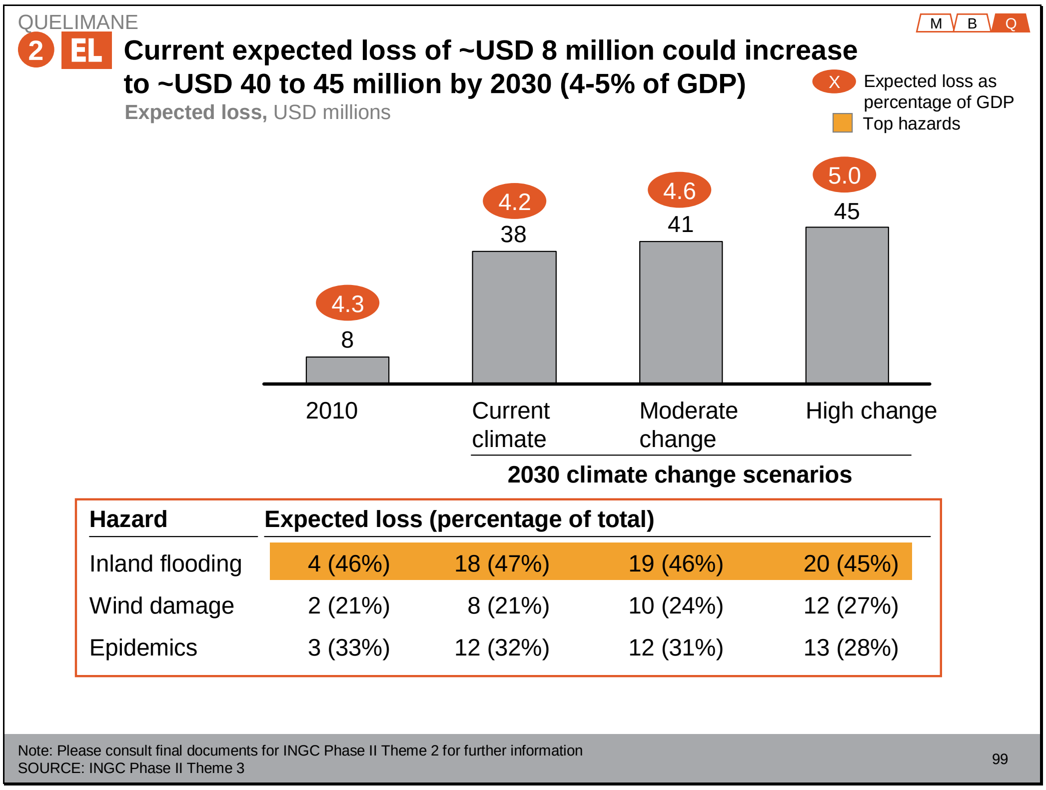
Expected loss, USD millions

Range from current climate to high climate change scenario

X Expected loss as percentage of GDP

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 100



QUELIMANE

M B Q

2 EL Current expected loss of ~USD 8 million could increase to ~USD 40 to 45 million by 2030 (4-5% of GDP)

Expected loss, USD millions

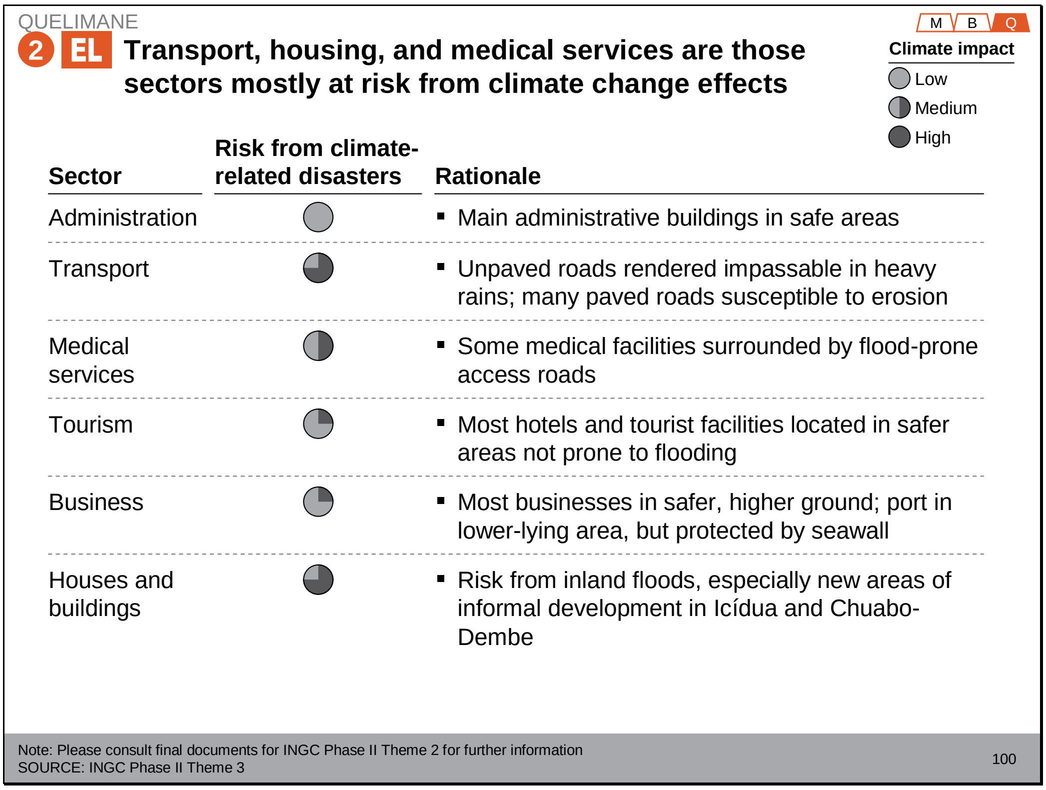
X Expected loss as percentage of GDP

🟧 Top hazards

Hazard	**Expected loss (percentage of total)**			
Inland flooding	4 (46%)	18 (47%)	19 (46%)	20 (45%)
Wind damage	2 (21%)	8 (21%)	10 (24%)	12 (27%)
Epidemics	3 (33%)	12 (32%)	12 (31%)	13 (28%)

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 101



QUELIMANE

M B Q

2 EL Transport, housing, and medical services are those sectors mostly at risk from climate change effects

Climate impact
○ Low
◑ Medium
● High

Sector	**Risk from climate-related disasters**	**Rationale**
Administration	○	- Main administrative buildings in safe areas
Transport	◕	- Unpaved roads rendered impassable in heavy rains; many paved roads susceptible to erosion
Medical services	◑	- Some medical facilities surrounded by flood-prone access roads
Tourism	◔	- Most hotels and tourist facilities located in safer areas not prone to flooding
Business	◔	- Most businesses in safer, higher ground; port in lower-lying area, but protected by seawall
Houses and buildings	◕	- Risk from inland floods, especially new areas of informal development in Icídua and Chuabo-Dembe

Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 102

QUELIMANE

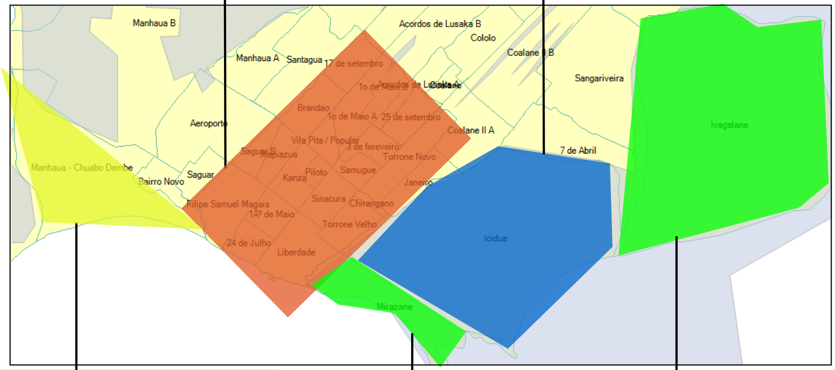
M B Q

2 EL New developments most at risk are informal housing in flood prone areas, and new development in erosion prone neighborhood

Major downtown business district and population center is largely safe from flooding

Low-lying flood-prone river basin of Icidua has significant, precarious mud & stick hut development

🟪 Flood-Prone Area
⬜ Bairros



Significant new development in erosion-prone areas of Munhaua-Chuabo Dembe

Further non-code housing being created in flood-prone Mirazane and Ivagalane, but to a lesser extent than Icidua

1 Flooding extent derived from 01/14/03 image, from the 01/01/03 - 02/17/03 flood, and 01/06/06 image, from the 12/22/05 – 02/07/06 flood.

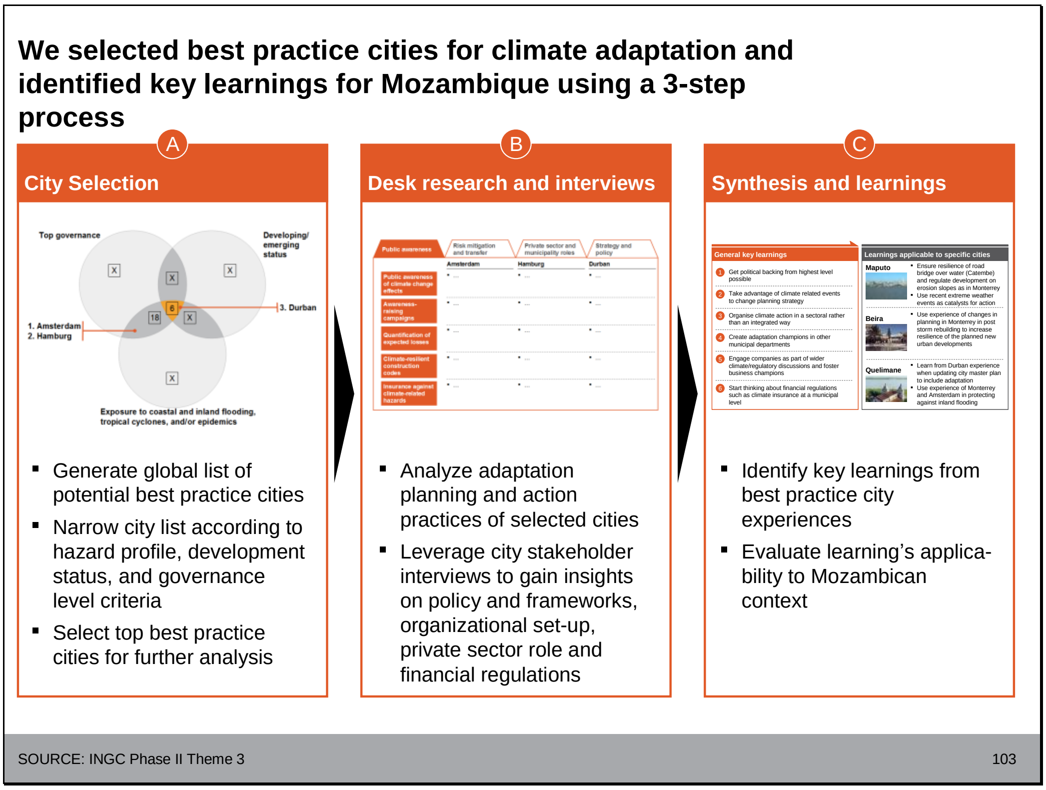
Note: Please consult final documents for INGC Phase II Theme 2 for further information
SOURCE: INGC Phase II Theme 3

SLIDE 103

Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 104



We selected best practice cities for climate adaptation and identified key learnings for Mozambique using a 3-step process

A City Selection

Top governance

Developing/ emerging status

1. Amsterdam
2. Hamburg

3. Durban

18

6

Exposure to coastal and inland flooding, tropical cyclones, and/or epidemics

- Generate global list of potential best practice cities
- Narrow city list according to hazard profile, development status, and governance level criteria
- Select top best practice cities for further analysis

B Desk research and interviews

Public awareness | Risk mitigation and transfer | Private sector and municipality roles | Strategy and policy

	Amsterdam	Hamburg	Durban
Public awareness of climate change effects	▪ …	▪ …	▪ …
Awareness-raising campaigns	▪ …	▪ …	▪ …
Quantification of expected losses	▪ …	▪ …	▪ …
Climate-resilient construction codes	▪ …	▪ …	▪ …
Insurance against climate-related hazards	▪ …	▪ …	▪ …

- Analyze adaptation planning and action practices of selected cities
- Leverage city stakeholder interviews to gain insights on policy and frameworks, organizational set-up, private sector role and financial regulations

C Synthesis and learnings

General key learnings

1. Get political backing from highest level possible
2. Take advantage of climate related events to change planning strategy
3. Organise climate action in a sectoral rather than an integrated way
4. Create adaptation champions in other municipal departments
5. Engage companies as part of wider climate/regulatory discussions and foster business champions
6. Start thinking about financial regulations such as climate insurance at a municipal level

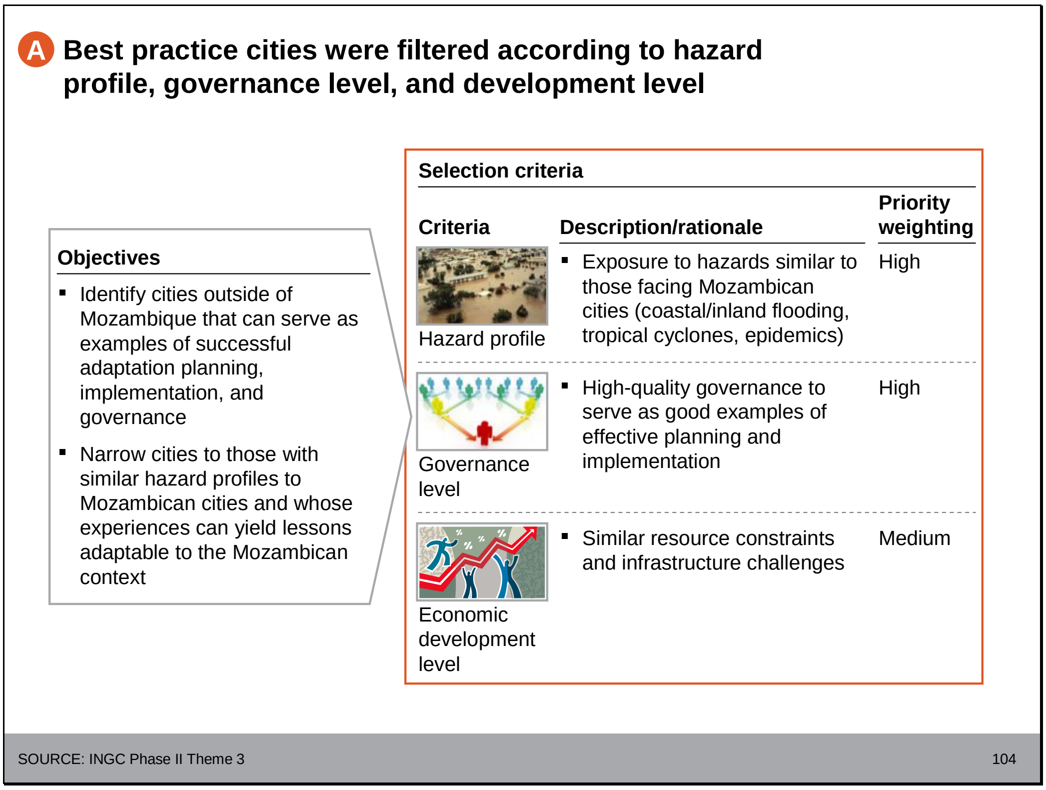
Learnings applicable to specific cities

Maputo	▪ Ensure resilience of road bridge over water (Catembe) and regulate development on erosion slopes as in Monterrey ▪ Use recent extreme weather events as catalysts for action
Beira	▪ Use experience of changes in planning in Monterrey in post storm rebuilding to increase resilience of the planned new urban developments
Quelimane	▪ Learn from Durban experience when updating city master plan to include adaptation ▪ Use experience of Monterrey and Amsterdam in protecting against inland flooding

- Identify key learnings from best practice city experiences
- Evaluate learning's applicability to Mozambican context

SOURCE: INGC Phase II Theme 3

SLIDE 105



A Best practice cities were filtered according to hazard profile, governance level, and development level

Objectives

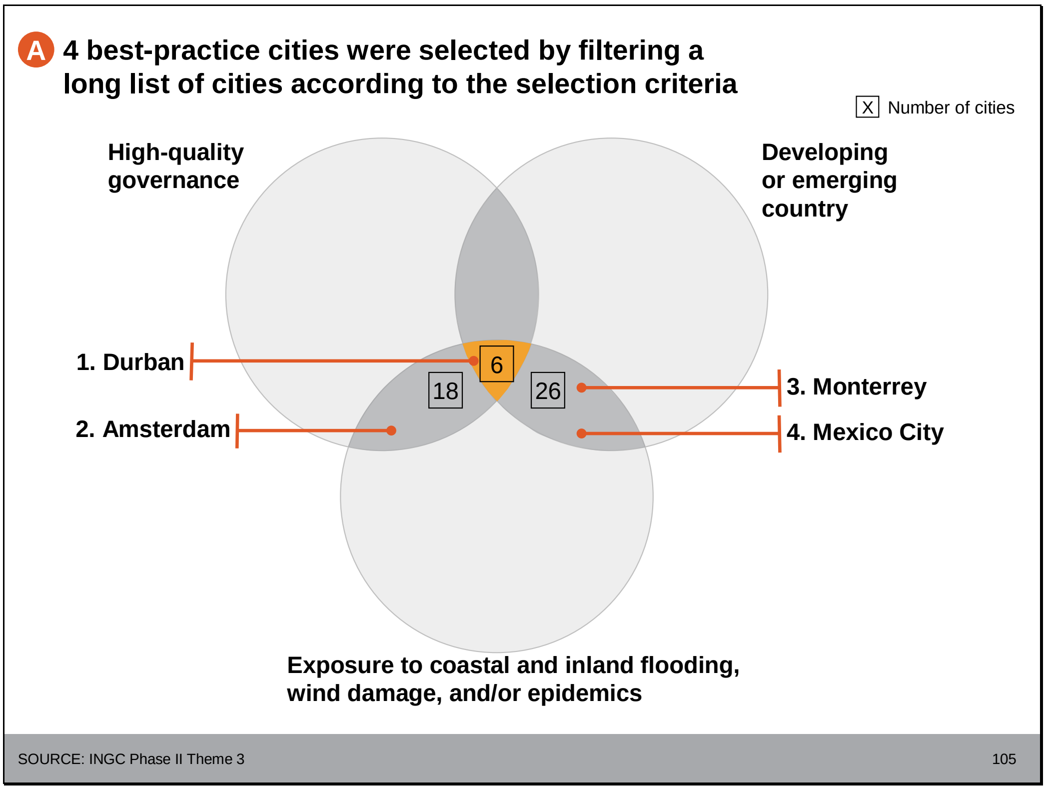
- Identify cities outside of Mozambique that can serve as examples of successful adaptation planning, implementation, and governance
- Narrow cities to those with similar hazard profiles to Mozambican cities and whose experiences can yield lessons adaptable to the Mozambican context

Selection criteria

Criteria	Description/rationale	Priority weighting
Hazard profile	▪ Exposure to hazards similar to those facing Mozambican cities (coastal/inland flooding, tropical cyclones, epidemics)	High
Governance level	▪ High-quality governance to serve as good examples of effective planning and implementation	High
Economic development level	▪ Similar resource constraints and infrastructure challenges	Medium

SOURCE: INGC Phase II Theme 3

SLIDE 106

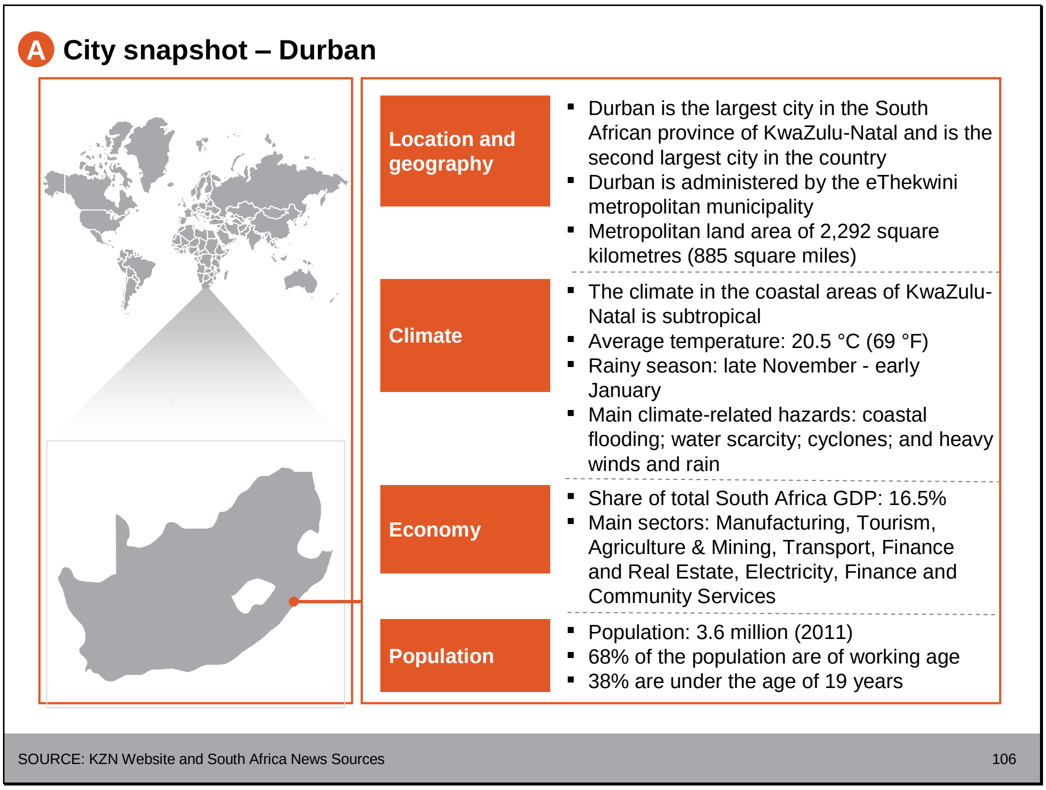


A 4 best-practice cities were selected by filtering a long list of cities according to the selection criteria

☒ Number of cities

SOURCE: INGC Phase II Theme 3

SLIDE 107

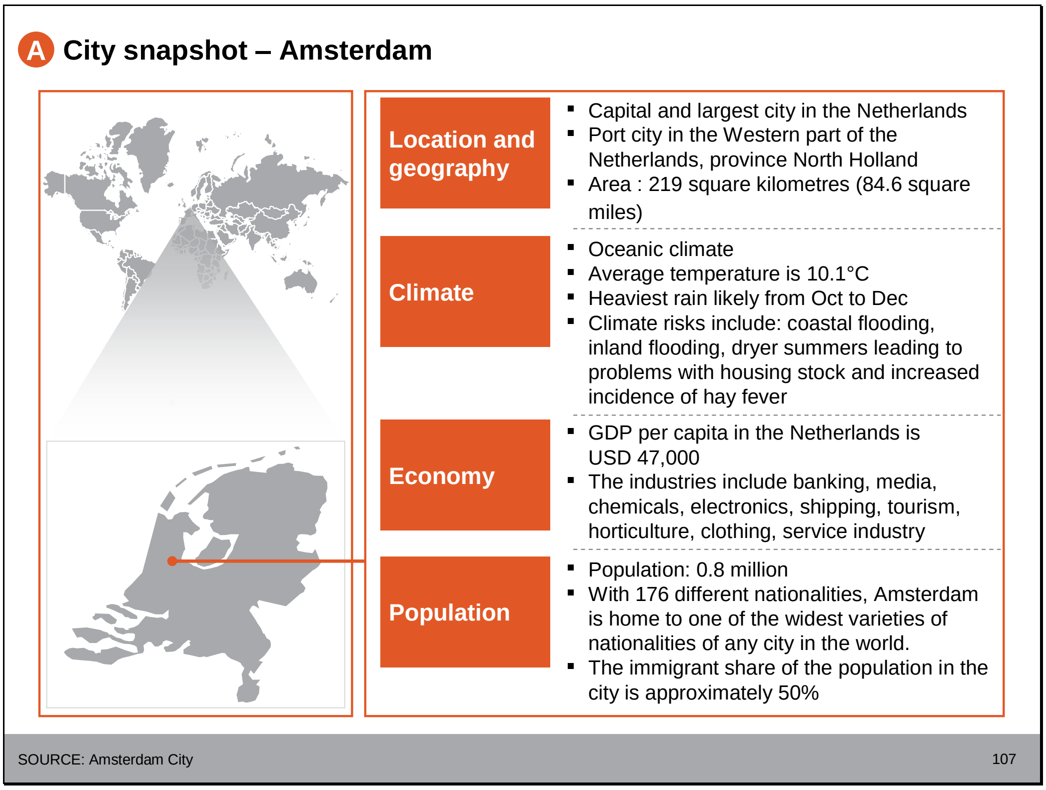


A City snapshot – Durban

Location and geography	▪ Durban is the largest city in the South African province of KwaZulu-Natal and is the second largest city in the country ▪ Durban is administered by the eThekwini metropolitan municipality ▪ Metropolitan land area of 2,292 square kilometres (885 square miles)
Climate	▪ The climate in the coastal areas of KwaZulu-Natal is subtropical ▪ Average temperature: 20.5 °C (69 °F) ▪ Rainy season: late November - early January ▪ Main climate-related hazards: coastal flooding; water scarcity; cyclones; and heavy winds and rain
Economy	▪ Share of total South Africa GDP: 16.5% ▪ Main sectors: Manufacturing, Tourism, Agriculture & Mining, Transport, Finance and Real Estate, Electricity, Finance and Community Services
Population	▪ Population: 3.6 million (2011) ▪ 68% of the population are of working age ▪ 38% are under the age of 19 years

SOURCE: KZN Website and South Africa News Sources

SLIDE 108



A City snapshot – Amsterdam

Location and geography
- Capital and largest city in the Netherlands
- Port city in the Western part of the Netherlands, province North Holland
- Area : 219 square kilometres (84.6 square miles)

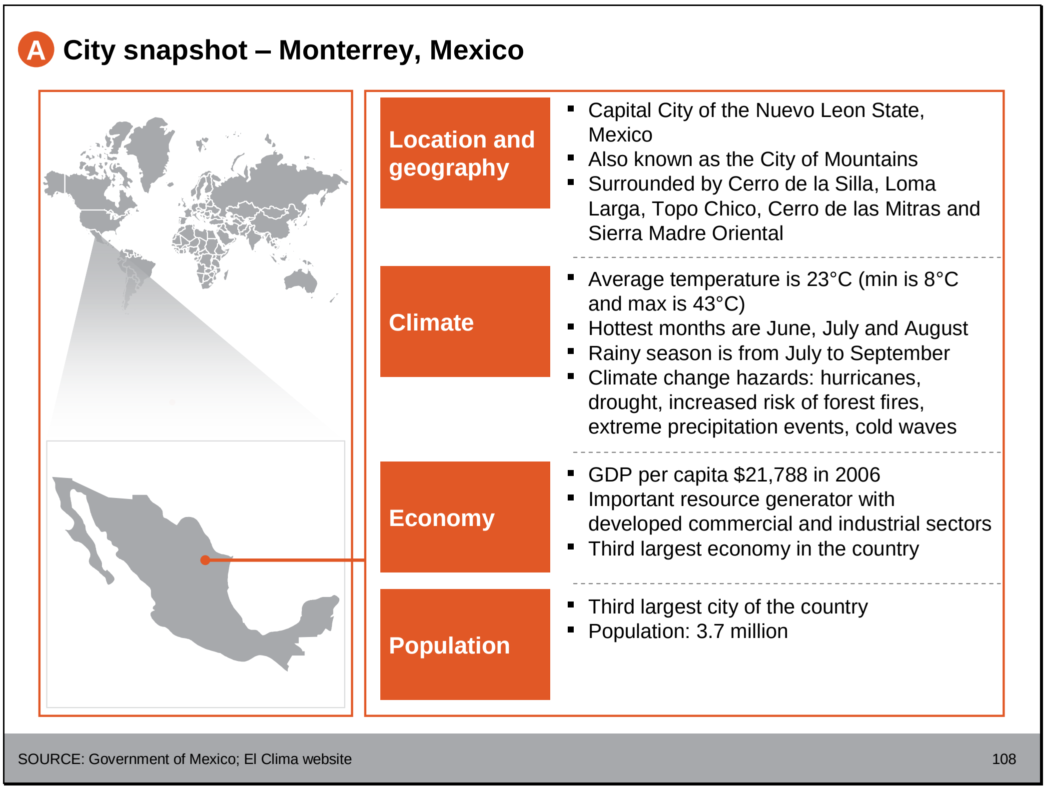
Climate
- Oceanic climate
- Average temperature is 10.1°C
- Heaviest rain likely from Oct to Dec
- Climate risks include: coastal flooding, inland flooding, dryer summers leading to problems with housing stock and increased incidence of hay fever

Economy
- GDP per capita in the Netherlands is USD 47,000
- The industries include banking, media, chemicals, electronics, shipping, tourism, horticulture, clothing, service industry

Population
- Population: 0.8 million
- With 176 different nationalities, Amsterdam is home to one of the widest varieties of nationalities of any city in the world.
- The immigrant share of the population in the city is approximately 50%

SOURCE: Amsterdam City

SLIDE 109



A City snapshot – Monterrey, Mexico

Location and geography
- Capital City of the Nuevo Leon State, Mexico
- Also known as the City of Mountains
- Surrounded by Cerro de la Silla, Loma Larga, Topo Chico, Cerro de las Mitras and Sierra Madre Oriental

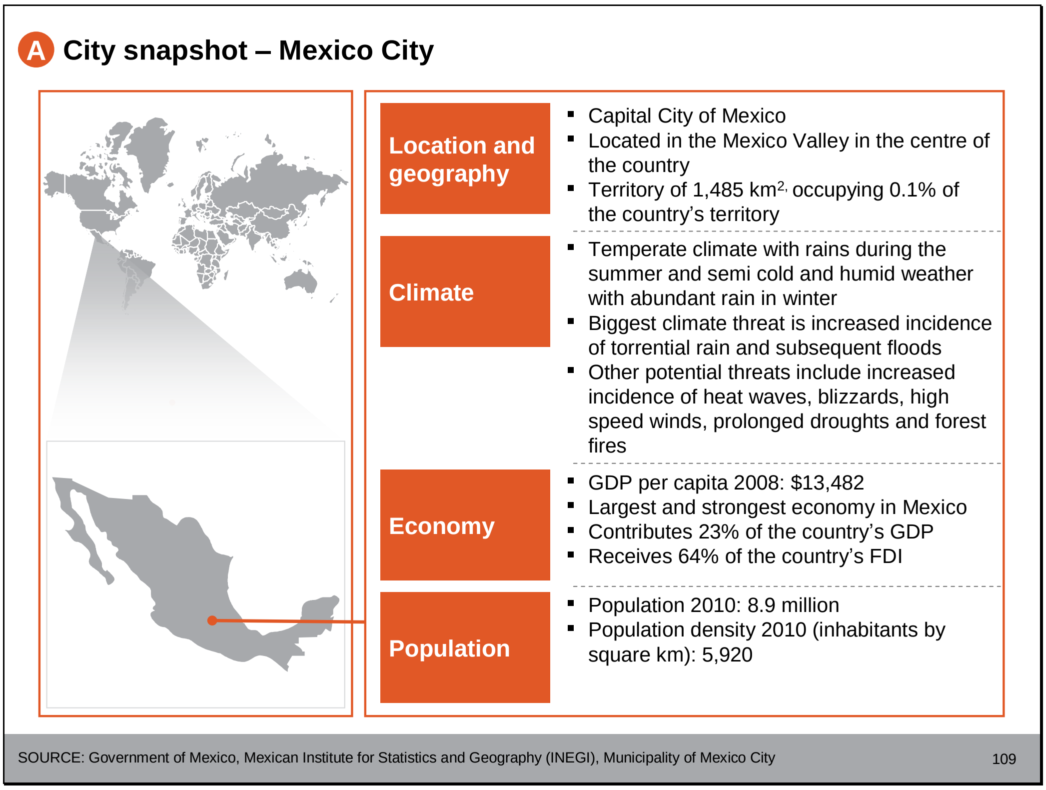
Climate
- Average temperature is 23°C (min is 8°C and max is 43°C)
- Hottest months are June, July and August
- Rainy season is from July to September
- Climate change hazards: hurricanes, drought, increased risk of forest fires, extreme precipitation events, cold waves

Economy
- GDP per capita $21,788 in 2006
- Important resource generator with developed commercial and industrial sectors
- Third largest economy in the country

Population
- Third largest city of the country
- Population: 3.7 million

SOURCE: Government of Mexico; El Clima website

SLIDE 110



A City snapshot – Mexico City

Location and geography

- Capital City of Mexico
- Located in the Mexico Valley in the centre of the country
- Territory of 1,485 km^{2,} occupying 0.1% of the country's territory

Climate

- Temperate climate with rains during the summer and semi cold and humid weather with abundant rain in winter
- Biggest climate threat is increased incidence of torrential rain and subsequent floods
- Other potential threats include increased incidence of heat waves, blizzards, high speed winds, prolonged droughts and forest fires

Economy

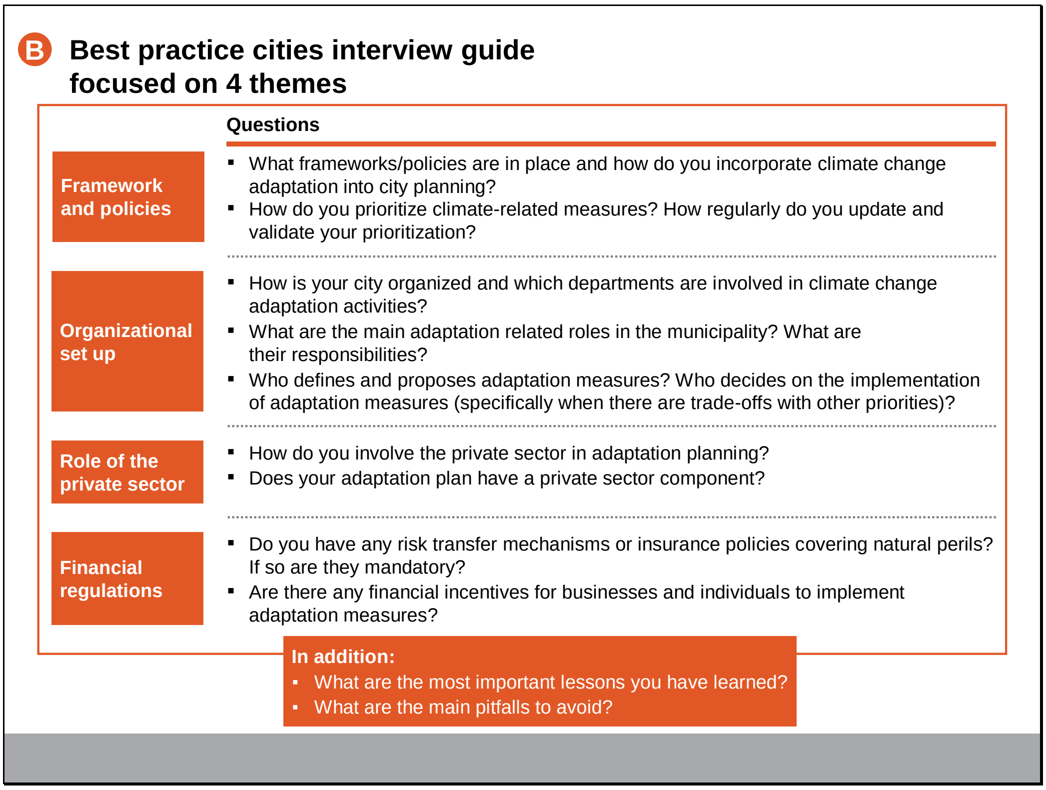
- GDP per capita 2008: $13,482
- Largest and strongest economy in Mexico
- Contributes 23% of the country's GDP
- Receives 64% of the country's FDI

Population

- Population 2010: 8.9 million
- Population density 2010 (inhabitants by square km): 5,920

SOURCE: Government of Mexico, Mexican Institute for Statistics and Geography (INEGI), Municipality of Mexico City

SLIDE 111



B Best practice cities interview guide focused on 4 themes

Questions

Framework and policies

- What frameworks/policies are in place and how do you incorporate climate change adaptation into city planning?
- How do you prioritize climate-related measures? How regularly do you update and validate your prioritization?

Organizational set up

- How is your city organized and which departments are involved in climate change adaptation activities?
- What are the main adaptation related roles in the municipality? What are their responsibilities?
- Who defines and proposes adaptation measures? Who decides on the implementation of adaptation measures (specifically when there are trade-offs with other priorities)?

Role of the private sector

- How do you involve the private sector in adaptation planning?
- Does your adaptation plan have a private sector component?

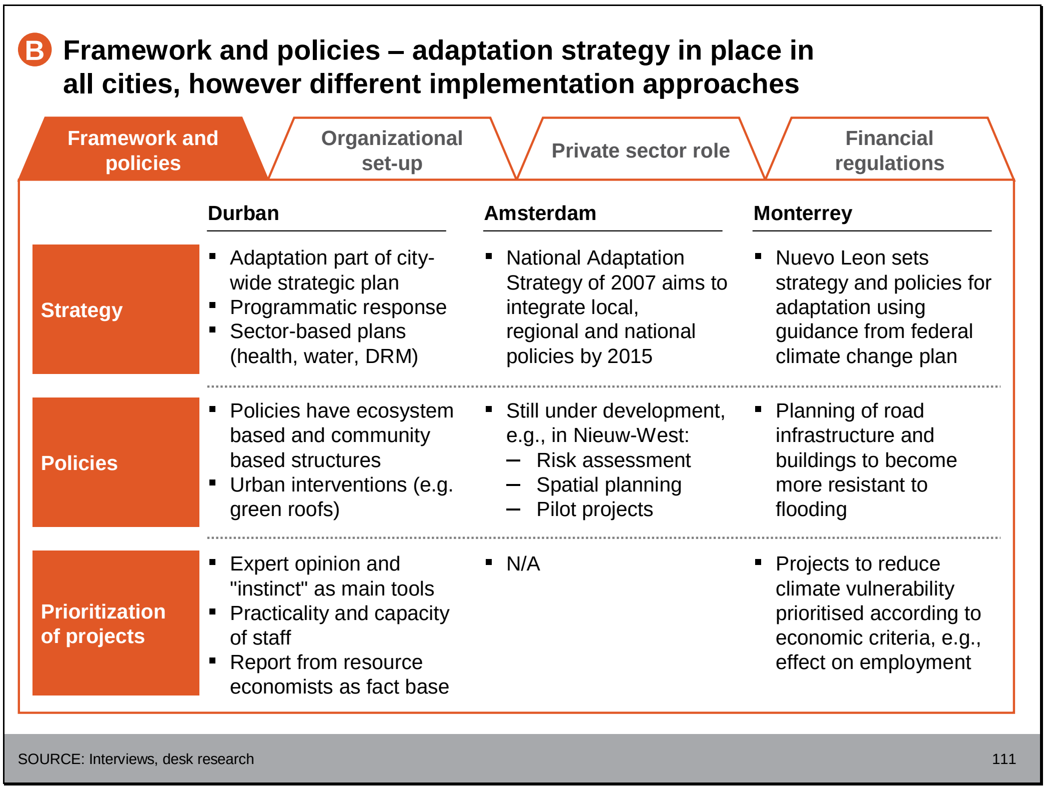
Financial regulations

- Do you have any risk transfer mechanisms or insurance policies covering natural perils? If so are they mandatory?
- Are there any financial incentives for businesses and individuals to implement adaptation measures?

In addition:

- What are the most important lessons you have learned?
- What are the main pitfalls to avoid?

SLIDE 112



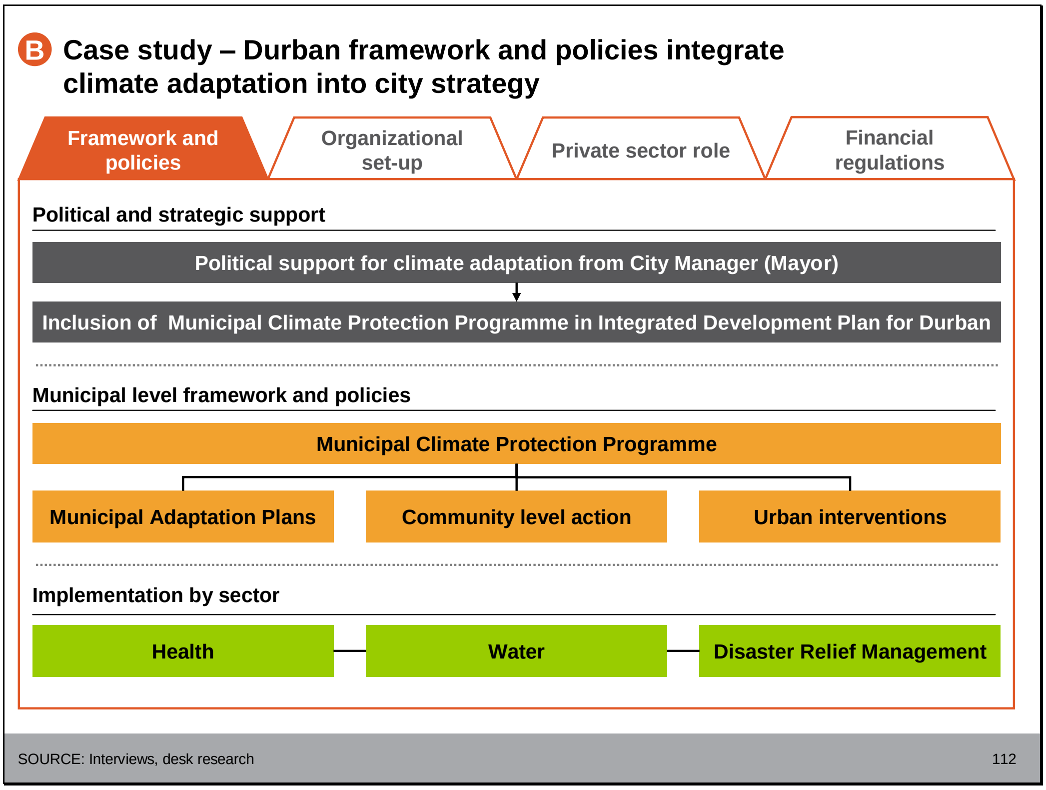
B Framework and policies – adaptation strategy in place in all cities, however different implementation approaches

Framework and policies | Organizational set-up | Private sector role | Financial regulations

	Durban	Amsterdam	Monterrey
Strategy	▪ Adaptation part of city-wide strategic plan ▪ Programmatic response ▪ Sector-based plans (health, water, DRM)	▪ National Adaptation Strategy of 2007 aims to integrate local, regional and national policies by 2015	▪ Nuevo Leon sets strategy and policies for adaptation using guidance from federal climate change plan
Policies	▪ Policies have ecosystem based and community based structures ▪ Urban interventions (e.g. green roofs)	▪ Still under development, e.g., in Nieuw-West: – Risk assessment – Spatial planning – Pilot projects	▪ Planning of road infrastructure and buildings to become more resistant to flooding
Prioritization of projects	▪ Expert opinion and "instinct" as main tools ▪ Practicality and capacity of staff ▪ Report from resource economists as fact base	▪ N/A	▪ Projects to reduce climate vulnerability prioritised according to economic criteria, e.g., effect on employment

SOURCE: Interviews, desk research

SLIDE 113



B Case study – Durban framework and policies integrate climate adaptation into city strategy

Framework and policies | Organizational set-up | Private sector role | Financial regulations

Political and strategic support

Political support for climate adaptation from City Manager (Mayor)

Inclusion of Municipal Climate Protection Programme in Integrated Development Plan for Durban

Municipal level framework and policies

Municipal Climate Protection Programme

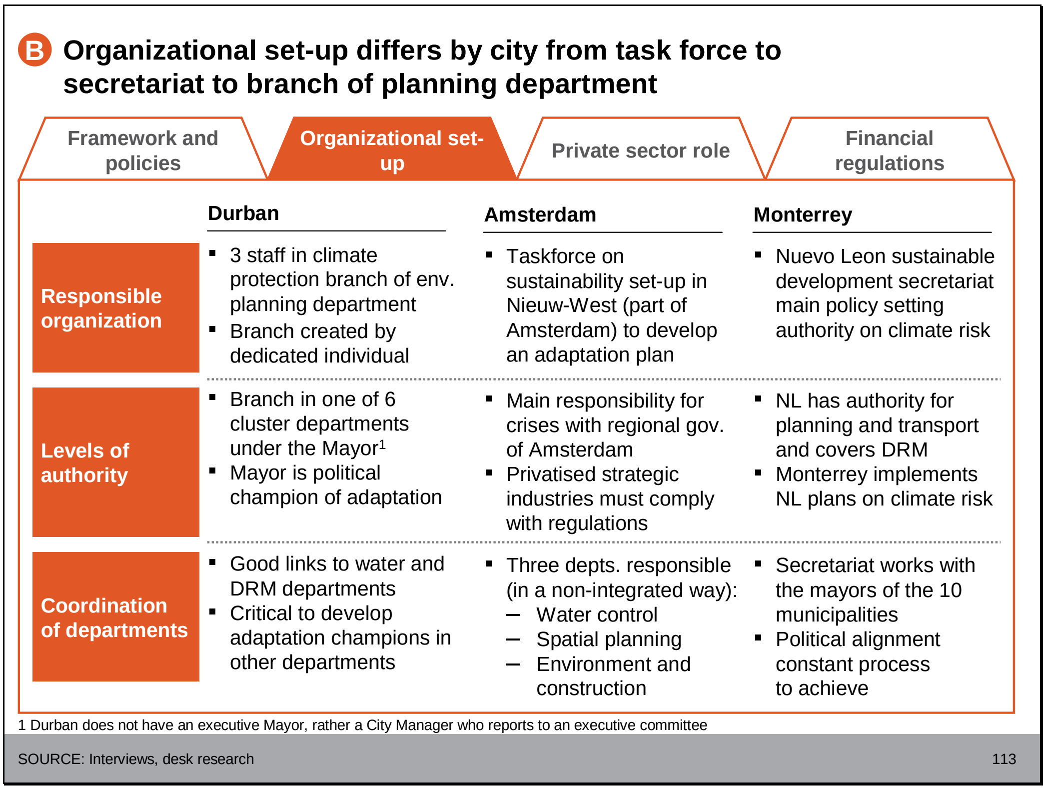
Municipal Adaptation Plans | Community level action | Urban interventions

Implementation by sector

Health – Water – Disaster Relief Management

SOURCE: Interviews, desk research

SLIDE 114



B Organizational set-up differs by city from task force to secretariat to branch of planning department

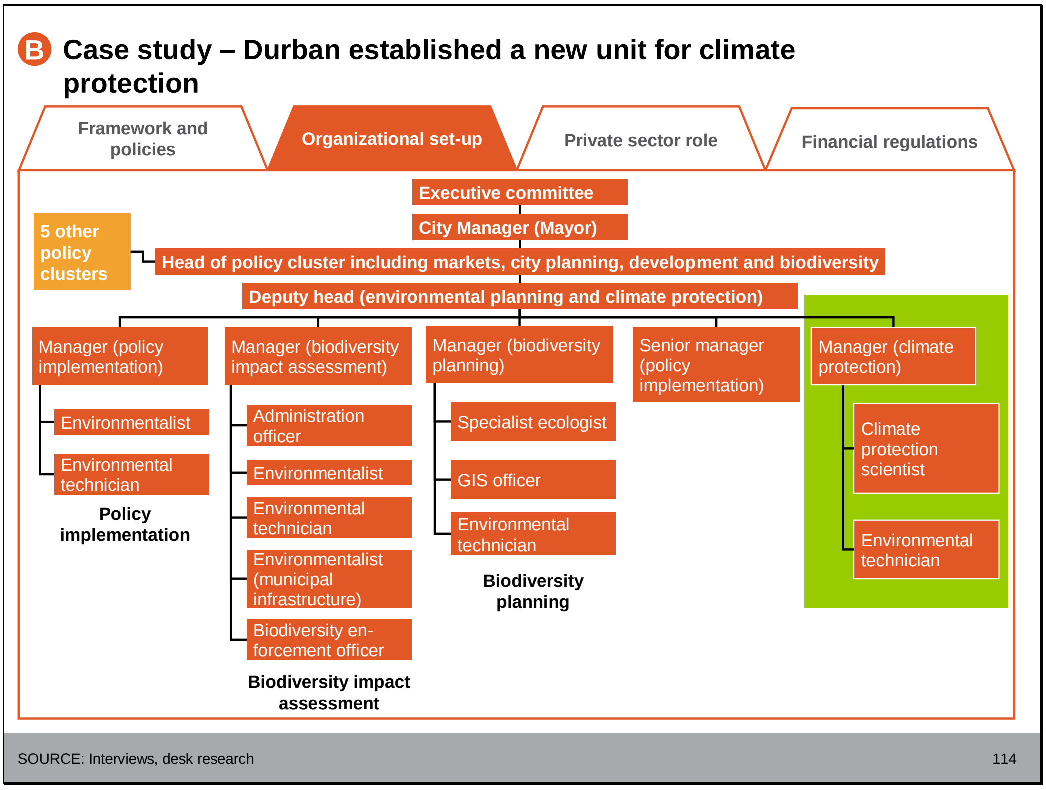
Framework and policies | **Organizational set-up** | Private sector role | Financial regulations

	Durban	Amsterdam	Monterrey
Responsible organization	▪ 3 staff in climate protection branch of env. planning department ▪ Branch created by dedicated individual	▪ Taskforce on sustainability set-up in Nieuw-West (part of Amsterdam) to develop an adaptation plan	▪ Nuevo Leon sustainable development secretariat main policy setting authority on climate risk
Levels of authority	▪ Branch in one of 6 cluster departments under the Mayor[1] ▪ Mayor is political champion of adaptation	▪ Main responsibility for crises with regional gov. of Amsterdam ▪ Privatised strategic industries must comply with regulations	▪ NL has authority for planning and transport and covers DRM ▪ Monterrey implements NL plans on climate risk
Coordination of departments	▪ Good links to water and DRM departments ▪ Critical to develop adaptation champions in other departments	▪ Three depts. responsible (in a non-integrated way): – Water control – Spatial planning – Environment and construction	▪ Secretariat works with the mayors of the 10 municipalities ▪ Political alignment constant process to achieve

[1] Durban does not have an executive Mayor, rather a City Manager who reports to an executive committee

SOURCE: Interviews, desk research

SLIDE 115

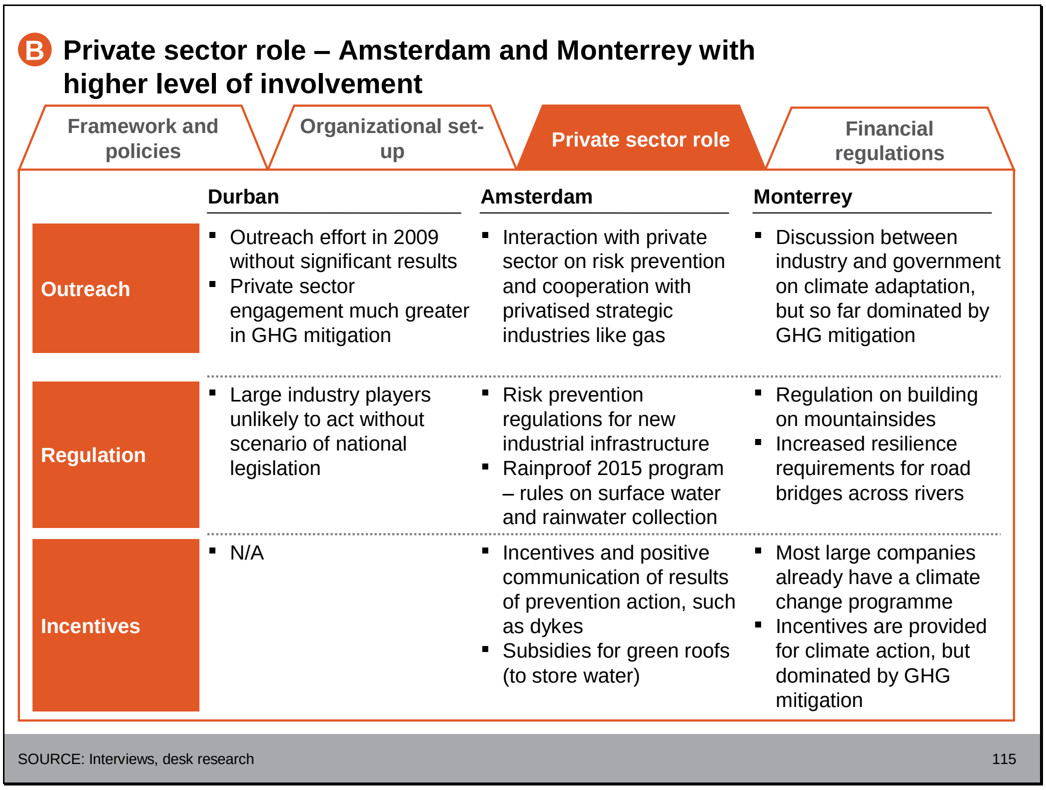


B Case study – Durban established a new unit for climate protection

Framework and policies | **Organizational set-up** | Private sector role | Financial regulations

SOURCE: Interviews, desk research

SLIDE 116



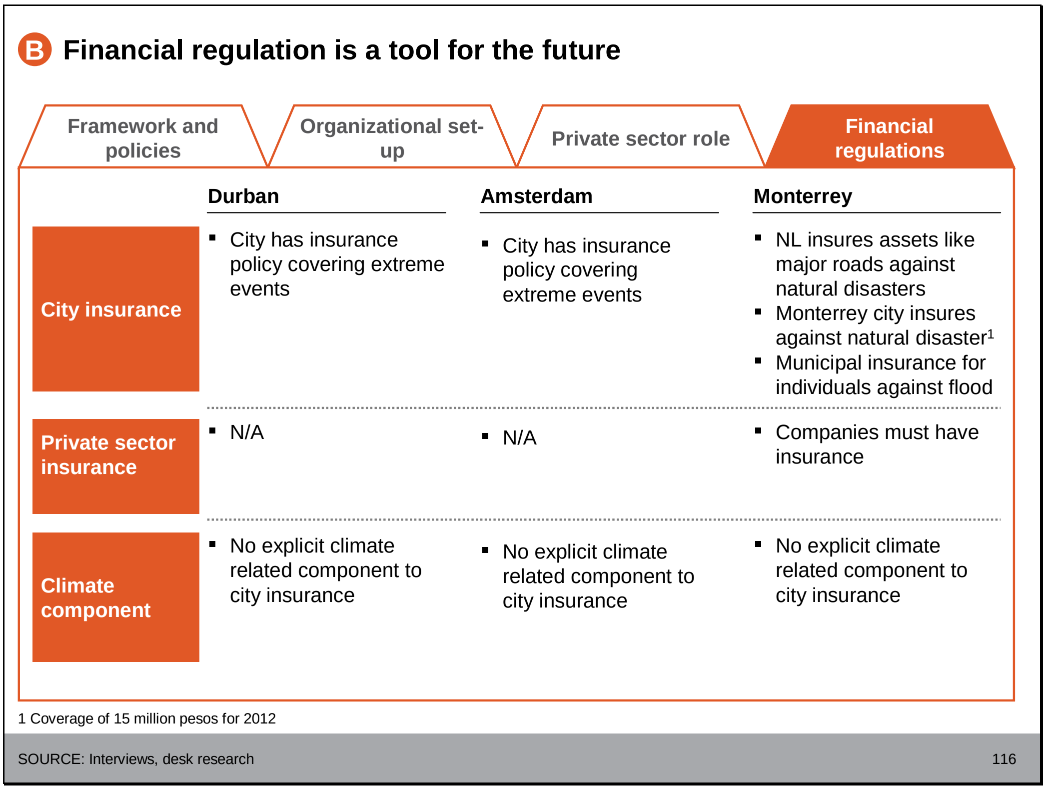
B Private sector role – Amsterdam and Monterrey with higher level of involvement

Framework and policies | Organizational set-up | **Private sector role** | Financial regulations

	Durban	Amsterdam	Monterrey
Outreach	▪ Outreach effort in 2009 without significant results ▪ Private sector engagement much greater in GHG mitigation	▪ Interaction with private sector on risk prevention and cooperation with privatised strategic industries like gas	▪ Discussion between industry and government on climate adaptation, but so far dominated by GHG mitigation
Regulation	▪ Large industry players unlikely to act without scenario of national legislation	▪ Risk prevention regulations for new industrial infrastructure ▪ Rainproof 2015 program – rules on surface water and rainwater collection	▪ Regulation on building on mountainsides ▪ Increased resilience requirements for road bridges across rivers
Incentives	▪ N/A	▪ Incentives and positive communication of results of prevention action, such as dykes ▪ Subsidies for green roofs (to store water)	▪ Most large companies already have a climate change programme ▪ Incentives are provided for climate action, but dominated by GHG mitigation

SOURCE: Interviews, desk research

SLIDE 117



B Financial regulation is a tool for the future

Framework and policies | Organizational set-up | Private sector role | **Financial regulations**

	Durban	Amsterdam	Monterrey
City insurance	▪ City has insurance policy covering extreme events	▪ City has insurance policy covering extreme events	▪ NL insures assets like major roads against natural disasters ▪ Monterrey city insures against natural disaster[1] ▪ Municipal insurance for individuals against flood
Private sector insurance	▪ N/A	▪ N/A	▪ Companies must have insurance
Climate component	▪ No explicit climate related component to city insurance	▪ No explicit climate related component to city insurance	▪ No explicit climate related component to city insurance

1 Coverage of 15 million pesos for 2012

SOURCE: Interviews, desk research

SLIDE 118

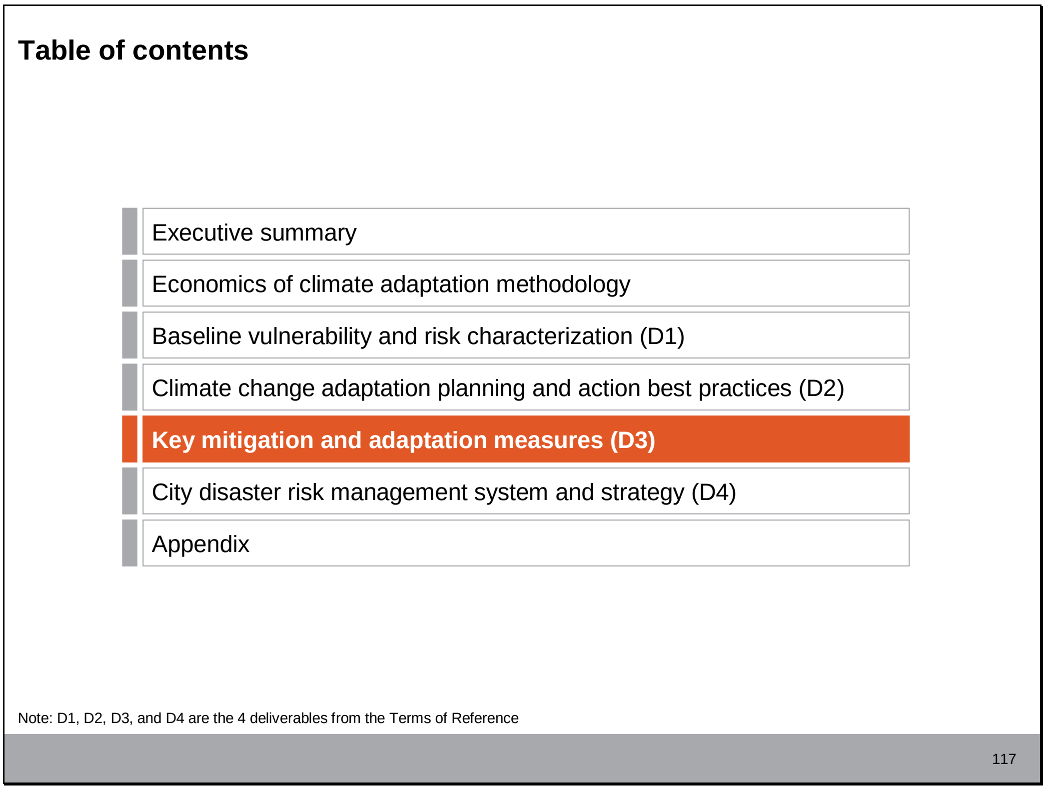
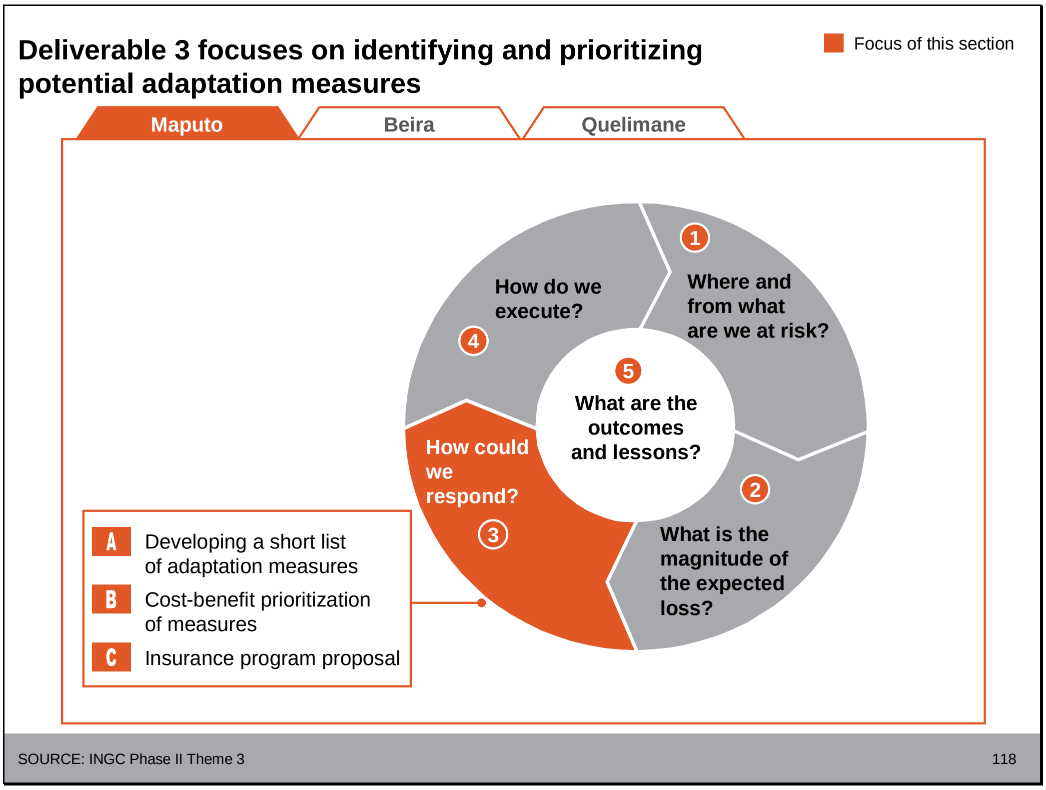


Table of contents

- Executive summary
- Economics of climate adaptation methodology
- Baseline vulnerability and risk characterization (D1)
- Climate change adaptation planning and action best practices (D2)
- **Key mitigation and adaptation measures (D3)**
- City disaster risk management system and strategy (D4)
- Appendix

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

SLIDE 119



Deliverable 3 focuses on identifying and prioritizing potential adaptation measures

🟥 Focus of this section

Maputo | Beira | Quelimane

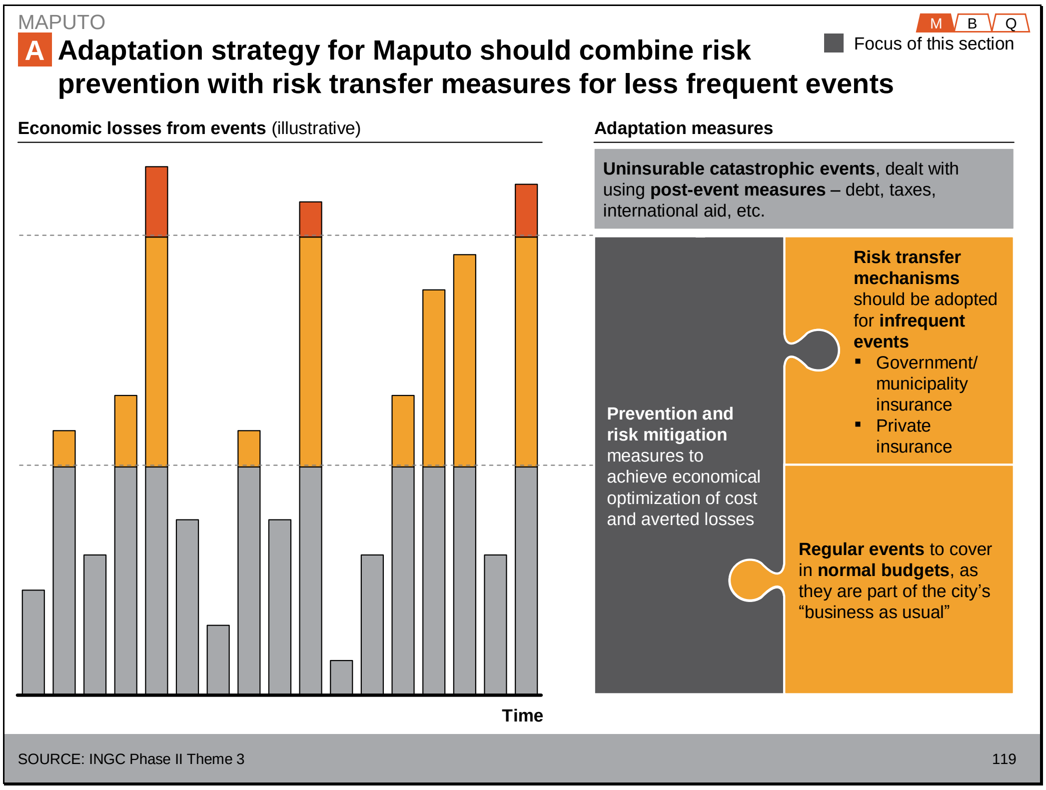
A Developing a short list of adaptation measures

B Cost-benefit prioritization of measures

C Insurance program proposal

SOURCE: INGC Phase II Theme 3

SLIDE 120



MAPUTO

A Adaptation strategy for Maputo should combine risk prevention with risk transfer measures for less frequent events

▨ Focus of this section

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

Risk transfer mechanisms should be adopted for **infrequent events**

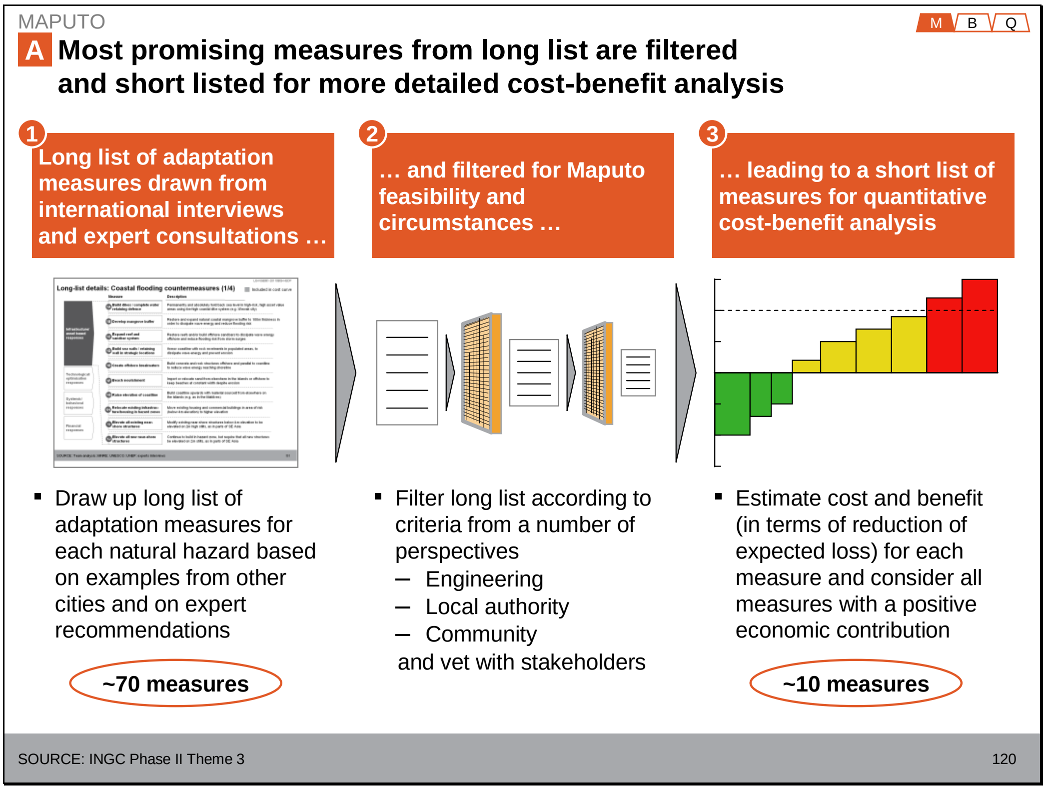
- Government/ municipality insurance
- Private insurance

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

119

SLIDE 121



MAPUTO

A Most promising measures from long list are filtered and short listed for more detailed cost-benefit analysis

① **Long list of adaptation measures drawn from international interviews and expert consultations …**

- Draw up long list of adaptation measures for each natural hazard based on examples from other cities and on expert recommendations

~70 measures

② **… and filtered for Maputo feasibility and circumstances …**

- Filter long list according to criteria from a number of perspectives
  - Engineering
  - Local authority
  - Community

  and vet with stakeholders

③ **… leading to a short list of measures for quantitative cost-benefit analysis**

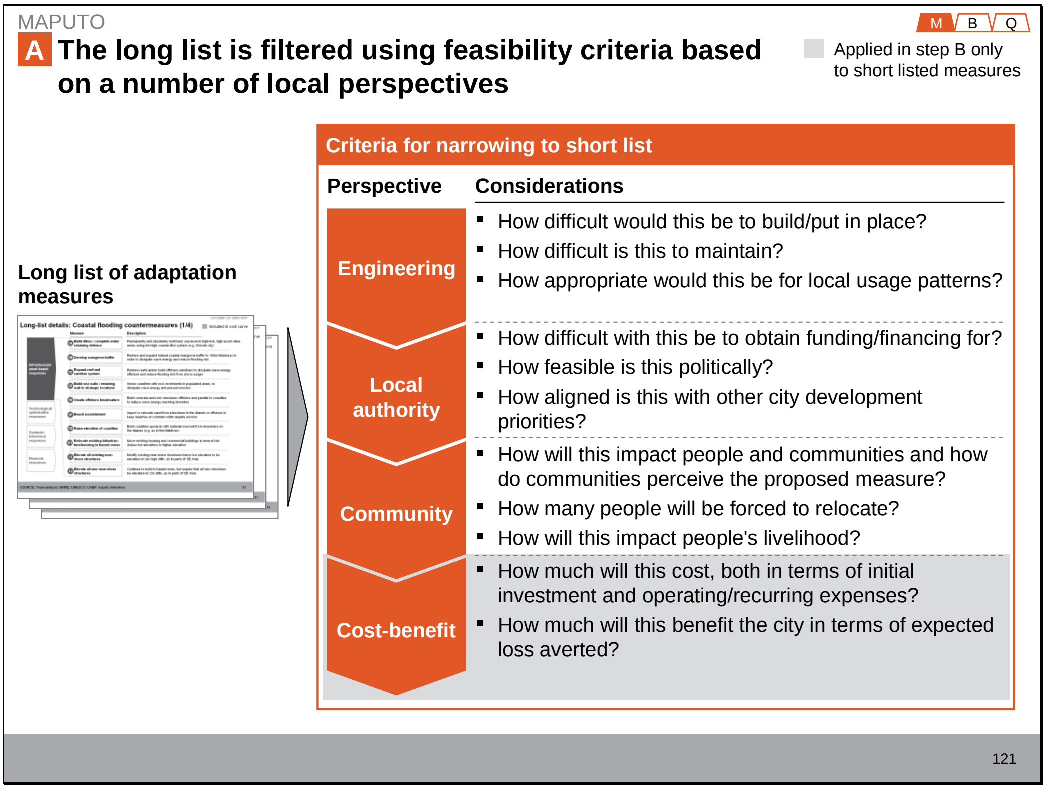
- Estimate cost and benefit (in terms of reduction of expected loss) for each measure and consider all measures with a positive economic contribution

~10 measures

SOURCE: INGC Phase II Theme 3

120

SLIDE 122



MAPUTO

M | B | Q

A The long list is filtered using feasibility criteria based on a number of local perspectives

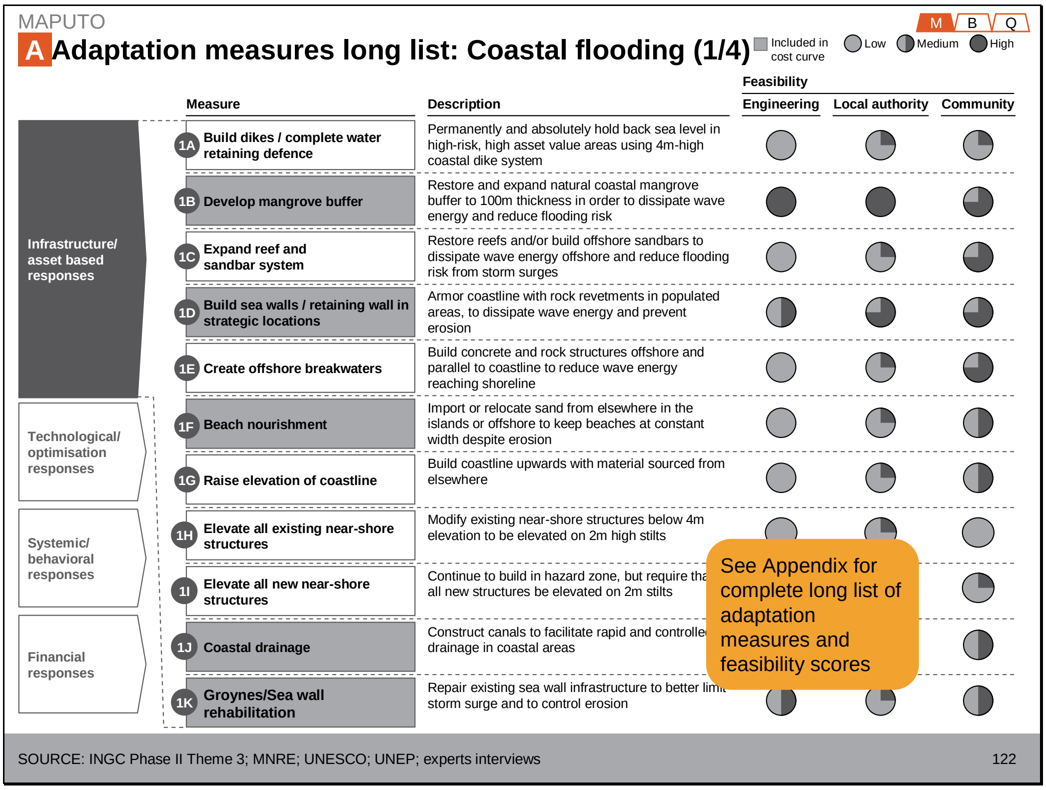
▨ Applied in step B only to short listed measures

Long list of adaptation measures

Criteria for narrowing to short list

Perspective	Considerations
Engineering	▪ How difficult would this be to build/put in place? ▪ How difficult is this to maintain? ▪ How appropriate would this be for local usage patterns?
Local authority	▪ How difficult with this be to obtain funding/financing for? ▪ How feasible is this politically? ▪ How aligned is this with other city development priorities?
Community	▪ How will this impact people and communities and how do communities perceive the proposed measure? ▪ How many people will be forced to relocate? ▪ How will this impact people's livelihood?
Cost-benefit	▪ How much will this cost, both in terms of initial investment and operating/recurring expenses? ▪ How much will this benefit the city in terms of expected loss averted?

SLIDE 123



MAPUTO

M | B | Q

A Adaptation measures long list: Coastal flooding (1/4)

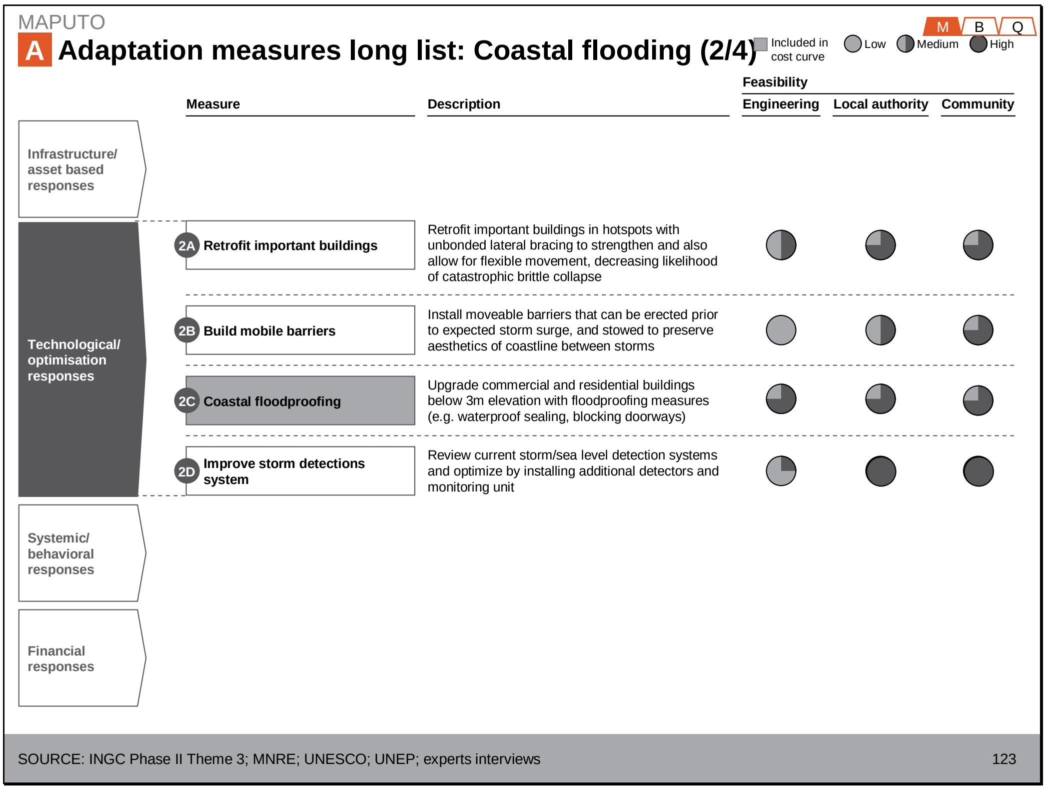
▨ Included in cost curve ○ Low ◑ Medium ● High

		Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Infrastructure/ asset based responses	1A	Build dikes / complete water retaining defence	Permanently and absolutely hold back sea level in high-risk, high asset value areas using 4m-high coastal dike system	○	◔	◔
	1B	Develop mangrove buffer ▨	Restore and expand natural coastal mangrove buffer to 100m thickness in order to dissipate wave energy and reduce flooding risk	●	●	◕
	1C	Expand reef and sandbar system	Restore reefs and/or build offshore sandbars to dissipate wave energy offshore and reduce flooding risk from storm surges	○	◔	◕
	1D	Build sea walls / retaining wall in strategic locations ▨	Armor coastline with rock revetments in populated areas, to dissipate wave energy and prevent erosion	◑	◕	◕
	1E	Create offshore breakwaters	Build concrete and rock structures offshore and parallel to coastline to reduce wave energy reaching shoreline	○	◔	◕
Technological/ optimisation responses	1F	Beach nourishment ▨	Import or relocate sand from elsewhere in the islands or offshore to keep beaches at constant width despite erosion	○	◔	◑
	1G	Raise elevation of coastline	Build coastline upwards with material sourced from elsewhere	○	◔	◑
Systemic/ behavioral responses	1H	Elevate all existing near-shore structures	Modify existing near-shore structures below 4m elevation to be elevated on 2m high stilts	○	◔	○
	1I	Elevate all new near-shore structures	Continue to build in hazard zone, but require tha all new structures be elevated on 2m stilts			◔
Financial responses	1J	Coastal drainage ▨	Construct canals to facilitate rapid and controlle drainage in coastal areas			◑
	1K	Groynes/Sea wall rehabilitation ▨	Repair existing sea wall infrastructure to better limi storm surge and to control erosion	◑	◔	◑

See Appendix for complete long list of adaptation measures and feasibility scores

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 124



MAPUTO

A Adaptation measures long list: Coastal flooding (2/4)

M B Q

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

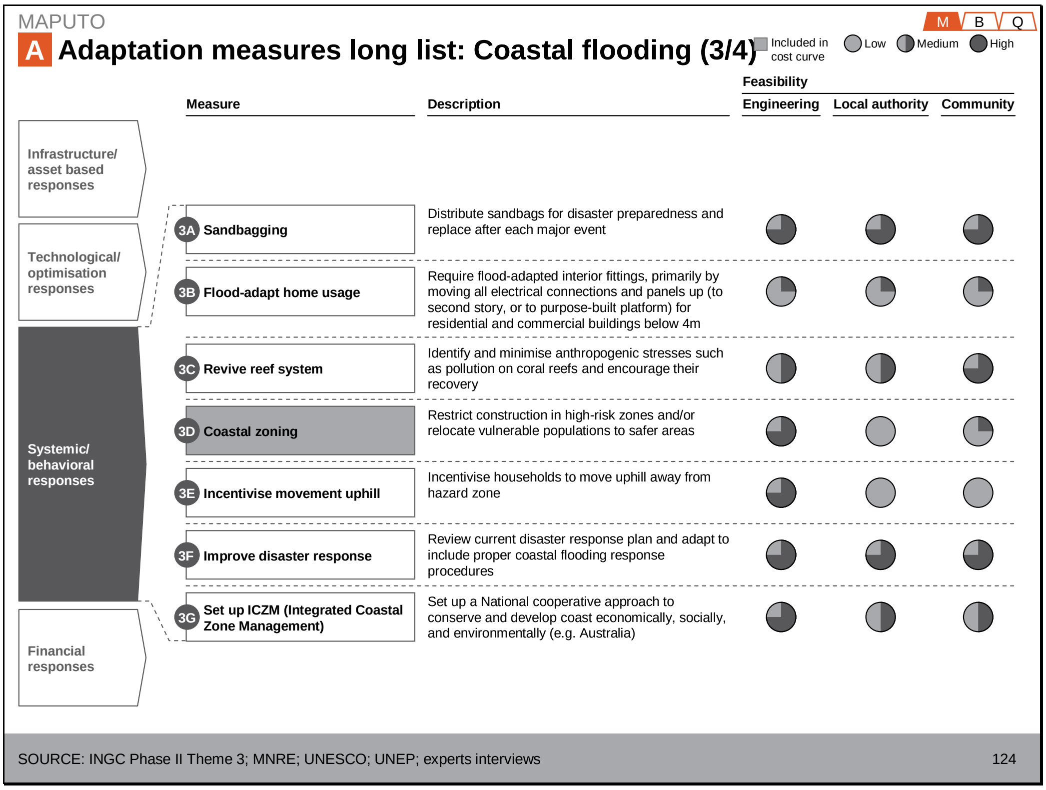
Systemic/ behavioral responses

Financial responses

Response type	Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Technological/ optimisation responses	2A Retrofit important buildings	Retrofit important buildings in hotspots with unbonded lateral bracing to strengthen and also allow for flexible movement, decreasing likelihood of catastrophic brittle collapse	◑	◕	◕
	2B Build mobile barriers	Install moveable barriers that can be erected prior to expected storm surge, and stowed to preserve aesthetics of coastline between storms	○	◑	◕
	▨ 2C Coastal floodproofing	Upgrade commercial and residential buildings below 3m elevation with floodproofing measures (e.g. waterproof sealing, blocking doorways)	◕	◕	◕
	2D Improve storm detections system	Review current storm/sea level detection systems and optimize by installing additional detectors and monitoring unit	◔	●	●

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 125



MAPUTO

A Adaptation measures long list: Coastal flooding (3/4)

M B Q

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

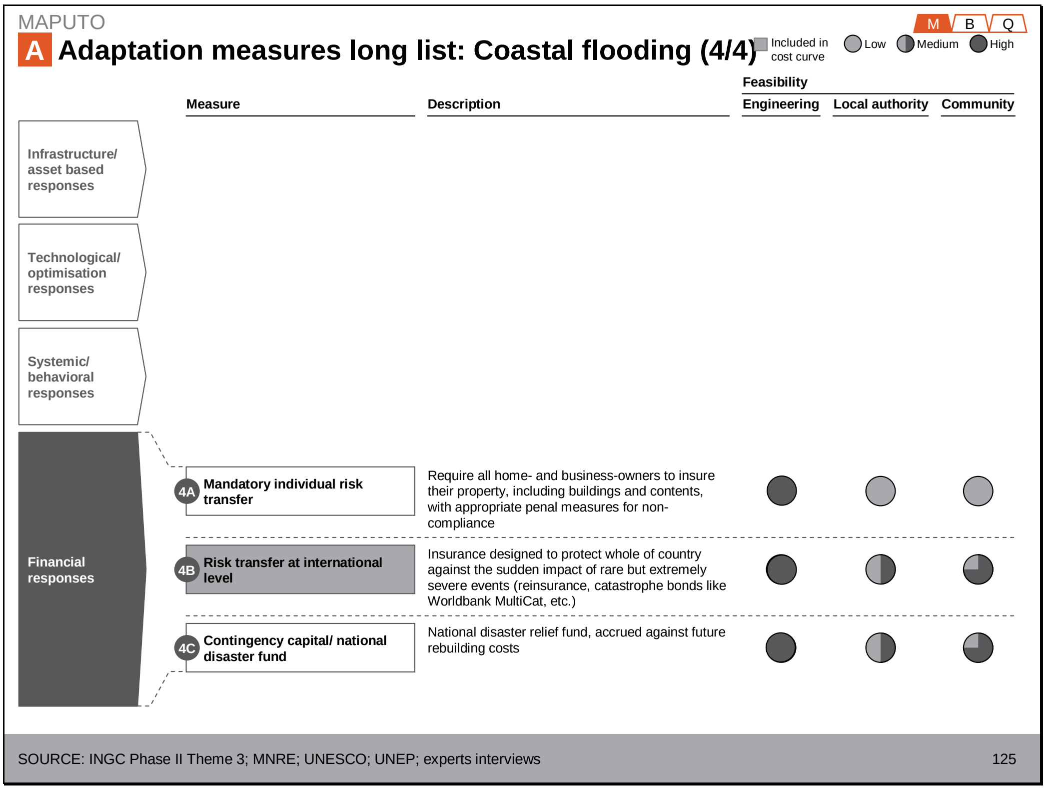
Systemic/ behavioral responses

Financial responses

Response type	Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Systemic/ behavioral responses	3A Sandbagging	Distribute sandbags for disaster preparedness and replace after each major event	◕	◕	◕
	3B Flood-adapt home usage	Require flood-adapted interior fittings, primarily by moving all electrical connections and panels up (to second story, or to purpose-built platform) for residential and commercial buildings below 4m	◔	◔	◔
	3C Revive reef system	Identify and minimise anthropogenic stresses such as pollution on coral reefs and encourage their recovery	◑	◑	◕
	▨ 3D Coastal zoning	Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	◕	○	◔
	3E Incentivise movement uphill	Incentivise households to move uphill away from hazard zone	◕	○	○
	3F Improve disaster response	Review current disaster response plan and adapt to include proper coastal flooding response procedures	◕	◕	◕
	3G Set up ICZM (Integrated Coastal Zone Management)	Set up a National cooperative approach to conserve and develop coast economically, socially, and environmentally (e.g. Australia)	◕	◑	◑

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 126



MAPUTO

M | B | Q

A Adaptation measures long list: Coastal flooding (4/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

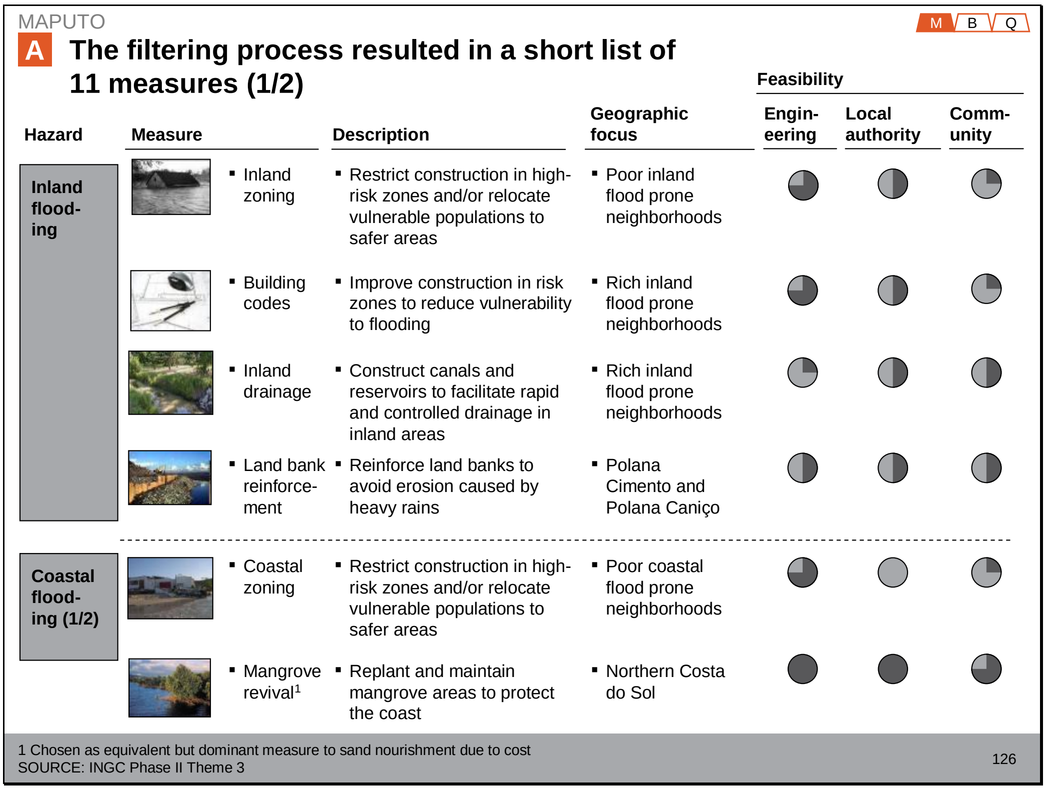
Systemic/ behavioral responses

Financial responses

	Measure	Description	Feasibility Engineering	 Local authority	 Community
4A	**Mandatory individual risk transfer**	Require all home- and business-owners to insure their property, including buildings and contents, with appropriate penal measures for non-compliance	●	○	○
4B	**Risk transfer at international level**	Insurance designed to protect whole of country against the sudden impact of rare but extremely severe events (reinsurance, catastrophe bonds like Worldbank MultiCat, etc.)	●	◑	◕
4C	**Contingency capital/ national disaster fund**	National disaster relief fund, accrued against future rebuilding costs	●	◑	◕

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 127



MAPUTO

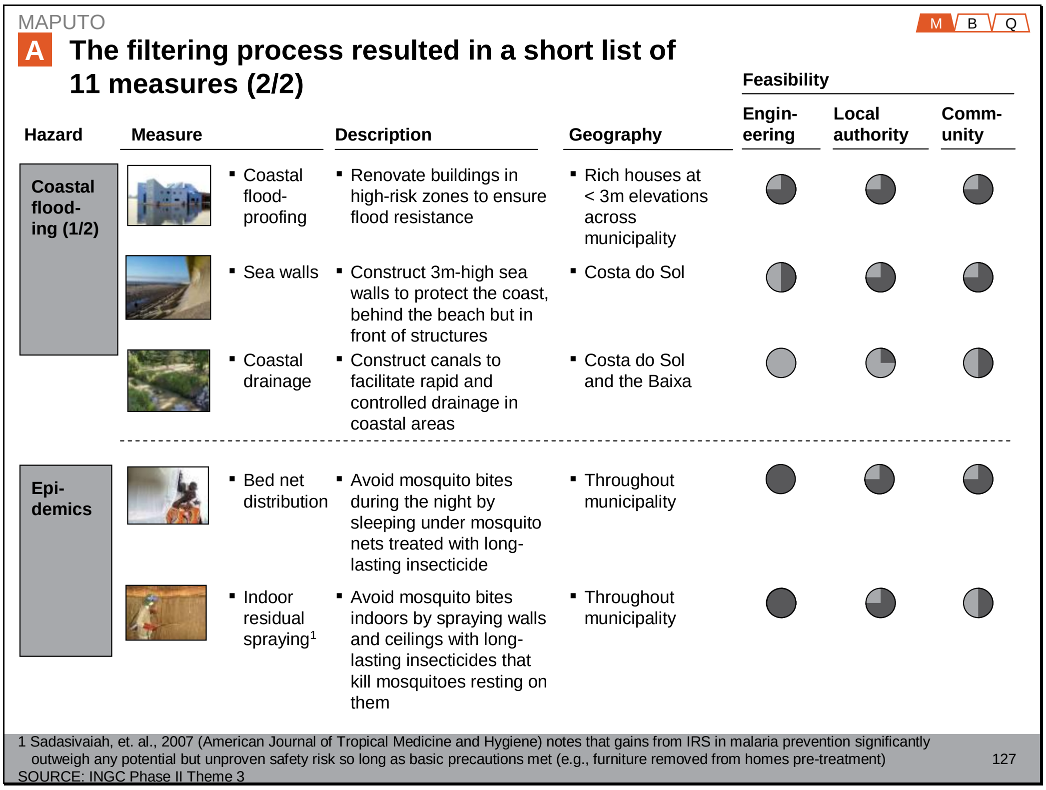
M | B | Q

A The filtering process resulted in a short list of 11 measures (1/2)

Hazard	Measure	Description	Geographic focus	Feasibility Engin-eering	 Local authority	 Comm-unity
Inland flood-ing	▪ Inland zoning	▪ Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	▪ Poor inland flood prone neighborhoods	◕	◑	◔
	▪ Building codes	▪ Improve construction in risk zones to reduce vulnerability to flooding	▪ Rich inland flood prone neighborhoods	◕	◑	◔
	▪ Inland drainage	▪ Construct canals and reservoirs to facilitate rapid and controlled drainage in inland areas	▪ Rich inland flood prone neighborhoods	◔	◑	◑
	▪ Land bank reinforce-ment	▪ Reinforce land banks to avoid erosion caused by heavy rains	▪ Polana Cimento and Polana Caniço	◑	◑	◑
Coastal flood-ing (1/2)	▪ Coastal zoning	▪ Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	▪ Poor coastal flood prone neighborhoods	◕	○	◔
	▪ Mangrove revival[1]	▪ Replant and maintain mangrove areas to protect the coast	▪ Northern Costa do Sol	●	●	◕

1 Chosen as equivalent but dominant measure to sand nourishment due to cost
SOURCE: INGC Phase II Theme 3

SLIDE 128



MAPUTO

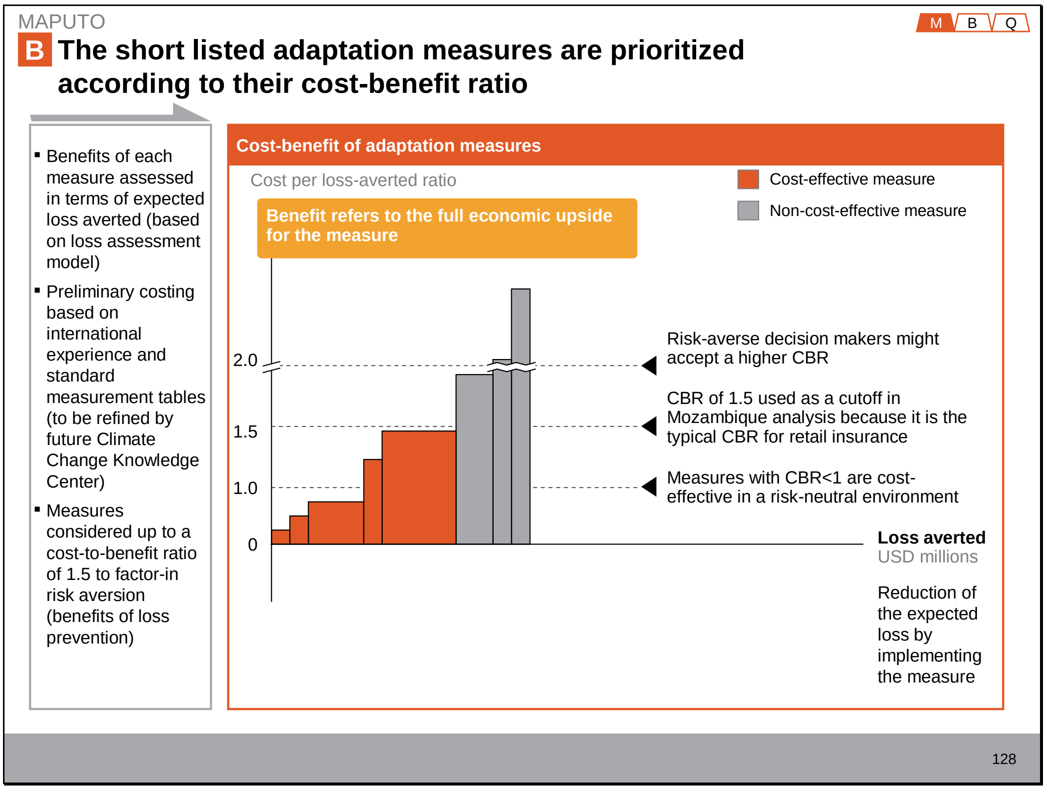
A The filtering process resulted in a short list of 11 measures (2/2)

Hazard	Measure	Description	Geography	Feasibility Engin-eering	Feasibility Local authority	Feasibility Comm-unity
Coastal flood-ing (1/2)	Coastal flood-proofing	Renovate buildings in high-risk zones to ensure flood resistance	Rich houses at < 3m elevations across municipality	◕	◕	◕
	Sea walls	Construct 3m-high sea walls to protect the coast, behind the beach but in front of structures	Costa do Sol	◑	◕	◕
	Coastal drainage	Construct canals to facilitate rapid and controlled drainage in coastal areas	Costa do Sol and the Baixa	○	◔	◑
Epi-demics	Bed net distribution	Avoid mosquito bites during the night by sleeping under mosquito nets treated with long-lasting insecticide	Throughout municipality	●	◕	◕
	Indoor residual spraying[1]	Avoid mosquito bites indoors by spraying walls and ceilings with long-lasting insecticides that kill mosquitoes resting on them	Throughout municipality	●	◕	◑

[1] Sadasivaiah, et. al., 2007 (American Journal of Tropical Medicine and Hygiene) notes that gains from IRS in malaria prevention significantly outweigh any potential but unproven safety risk so long as basic precautions met (e.g., furniture removed from homes pre-treatment)

SOURCE: INGC Phase II Theme 3

SLIDE 129



MAPUTO

B The short listed adaptation measures are prioritized according to their cost-benefit ratio

- Benefits of each measure assessed in terms of expected loss averted (based on loss assessment model)
- Preliminary costing based on international experience and standard measurement tables (to be refined by future Climate Change Knowledge Center)
- Measures considered up to a cost-to-benefit ratio of 1.5 to factor-in risk aversion (benefits of loss prevention)

Cost-benefit of adaptation measures

Cost per loss-averted ratio

🟥 Cost-effective measure

▨ Non-cost-effective measure

Benefit refers to the full economic upside for the measure

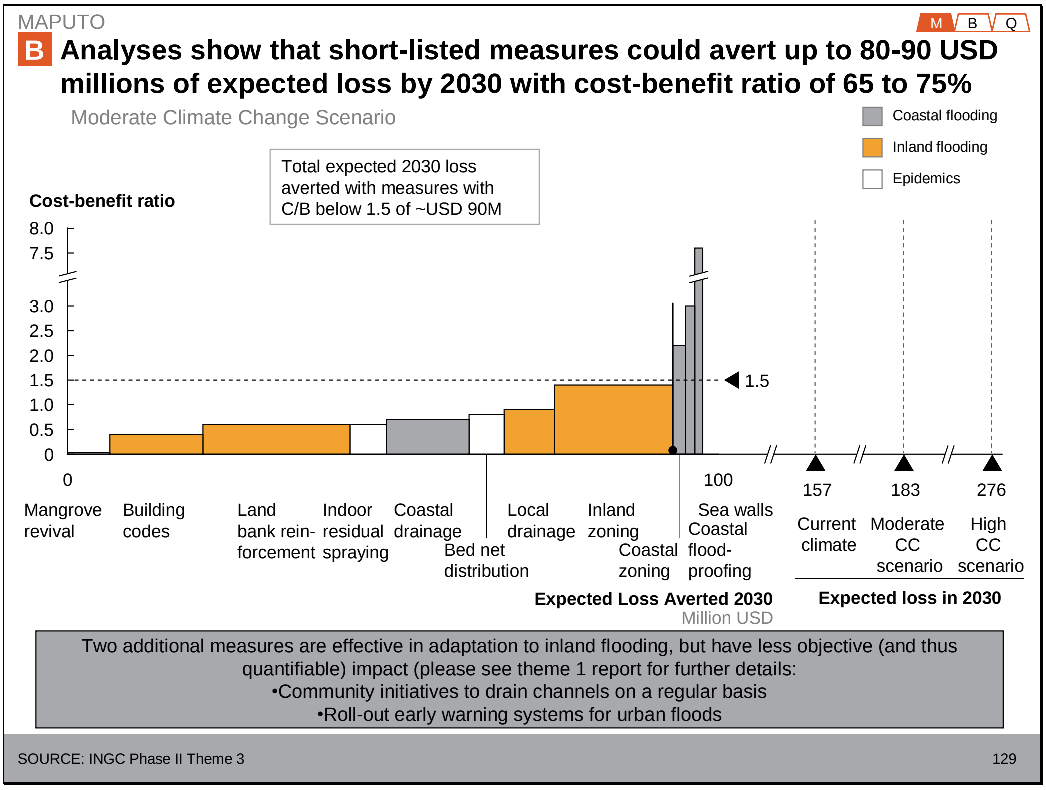
Risk-averse decision makers might accept a higher CBR

CBR of 1.5 used as a cutoff in Mozambique analysis because it is the typical CBR for retail insurance

Measures with CBR<1 are cost-effective in a risk-neutral environment

Reduction of the expected loss by implementing the measure

SLIDE 130



MAPUTO

M B Q

B Analyses show that short-listed measures could avert up to 80-90 USD millions of expected loss by 2030 with cost-benefit ratio of 65 to 75%

Moderate Climate Change Scenario

Two additional measures are effective in adaptation to inland flooding, but have less objective (and thus quantifiable) impact (please see theme 1 report for further details:
•Community initiatives to drain channels on a regular basis
•Roll-out early warning systems for urban floods

SOURCE: INGC Phase II Theme 3

129

NOTES FOR SLIDE 130:

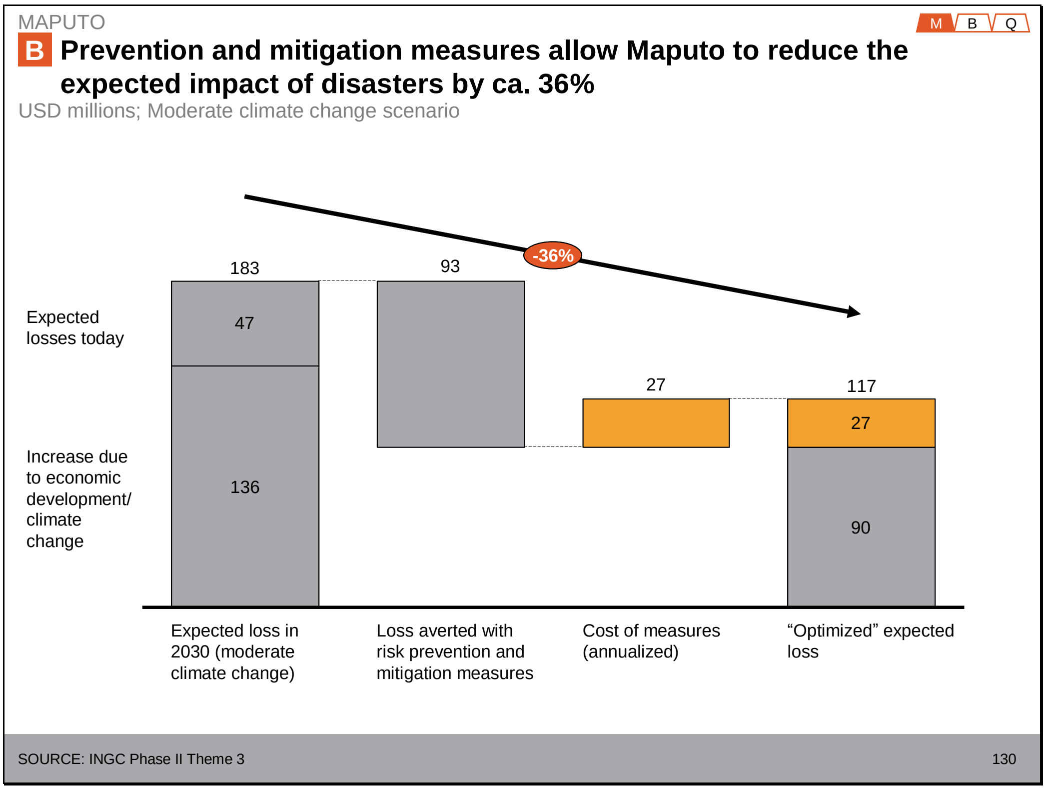
Response measures – Shortlist of adaptation measures module

Analyses show that short-listed measures could avert up to 80-90 USD millions of expected loss by 2030 with cost-benefit ration of 65 to 75%

This "cost curve" charts the most cost effective actions that Maputo could take in order avoid climate-caused losses by 2030.

The x axis shows the expected losses that will be incurred by Maputo by 2030. The three lines all the way to the right are the total expected losses under the three climate scenarios – Current Climate, Moderate CC and High CC.
The width of each bar on the cost curve represents the losses that would be avoided if the measure was put into place. Land bank reinforcement, for example, would avoid the most losses of all the measures. The bars are colored according to the type of risk the measure helps avoid (e.g., orange for inland flooding).
The y axis is the cost-benefit ratio for each measure, meaning how much the measure costs to implement relative to the benefits (the avoided costs from climate change) it produces. Measures with a C/B ratio of less than 1 produce more benefit than they cost. The bars are sorted in order of increasing cost to benefit, meaning that the ones on the left produce the most benefit for their cost while the ones to the right produce the least benefit for the most cost.
This curve notes the Expected Loss Averted by 2030 at USD 80-90 M, the sum of the costs avoided (the width of the bar) of all measures with a C/B Ratio less than 1.5, the proposed cut-off point for implementing a measure. The average of C/B ratios of the implemented measures is show to be 65 – 75%.

SLIDE 131



MAPUTO

M B Q

B Prevention and mitigation measures allow Maputo to reduce the expected impact of disasters by ca. 36%

USD millions; Moderate climate change scenario

SOURCE: INGC Phase II Theme 3

SLIDE 132

MAPUTO

M B Q

B Assumptions behind cost-benefit model for adaptation measures

High[2] | **Moderate** | Current climate[2]

Risk	Measure	Type	2011	2012	2013	…	2030	NPV	C/B
Inland flooding	Inland zoning	Costs	152953	256	256	…	256	155600	.63
		Benefits		11408	13011	…	40269	245720	
	Building codes	Costs	39293	0	0	…	0	39293	.43
		Benefits		4200	4761	…	14312	90646	
	Local drainage	Costs	20000	2000	2000	…	2000	40671	.44
		Benefits		4375	4960	…	14908	92073	
	Land bank reinforcement	Costs	38000	3800	3800	…	3800	77275	.56
		Benefits		6446	7343	…	22593	138196	
Coastal flooding	Coastal zoning	Costs	20700	40	40	…	40	21113	2.23
		Benefits		207	305	…	1969	9456	
	Mangrove revival	Costs	400	48	48	…	48	896	0.03
		Benefits		741	1062	…	6505	31651	
	Coastal flood-proofing	Costs	20585	0	0	…	0	20585	0.59
		Benefits		850	1201	…	7162	35097	
	Sea walls	Costs	30000	1500	1500	…	1500	45503	1.32
		Benefits		807	1156	…	7083	34465	
	Coastal drainage	Costs	22286	2229	2229	…	2229	45319	0.48
		Benefits		2278	3217	…	19184	94010	
Epidemics	Bed net distribution	Costs	3000	3000	3000	…	3000	34007	0.83
		Benefits		2681	2831	…	5364	41217	
	Indoor residual spraying	Costs	2181	2181	2181	…	2181	24722	0.57
		Benefits		2989	2989	…	5665	43526	

Key parameters
- Discount rate: 7%
- Time horizon: 20 yr.s
- Unit: 2010 US dollars

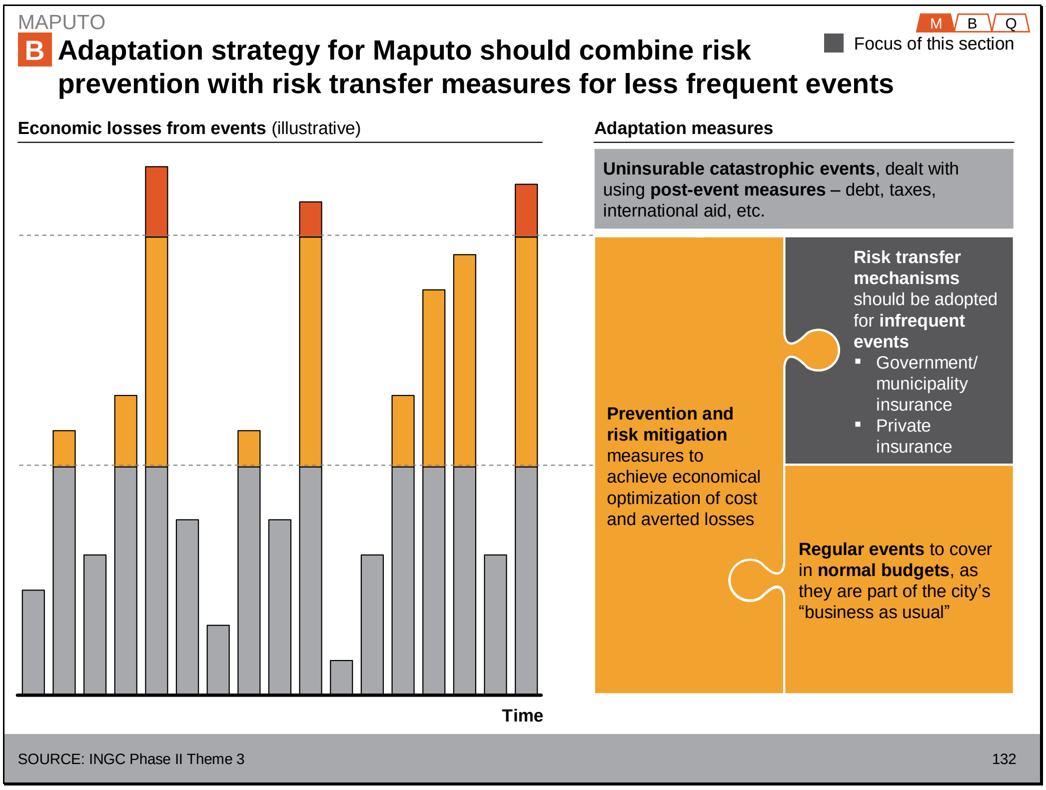
Cost-benefit ratio
Calculated as the net present value of costs over the net present value of benefits across 20 years

Costs[1]
- Initial capital investment occurs in year 1, subsequent recurring costs (e.g. maintenance) occur in years 2-20
- Costs are preliminary estimates to be refined/updated by planned Climate Change Know. Ctr.

Benefits
Benefits calculate economic losses averted in each year as a result of adaptation

1 Costs based on international benchmarks, tailored to local conditions and estimated project size (e.g. kilometers of sea wall or drainage canal)
2 Primary cost curves based on climate moderate scenario – underlying assumptions for High and Current Climate costing also available
SOURCE: INGC Phase II Theme 3

SLIDE 133



MAPUTO

B Adaptation strategy for Maputo should combine risk prevention with risk transfer measures for less frequent events

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

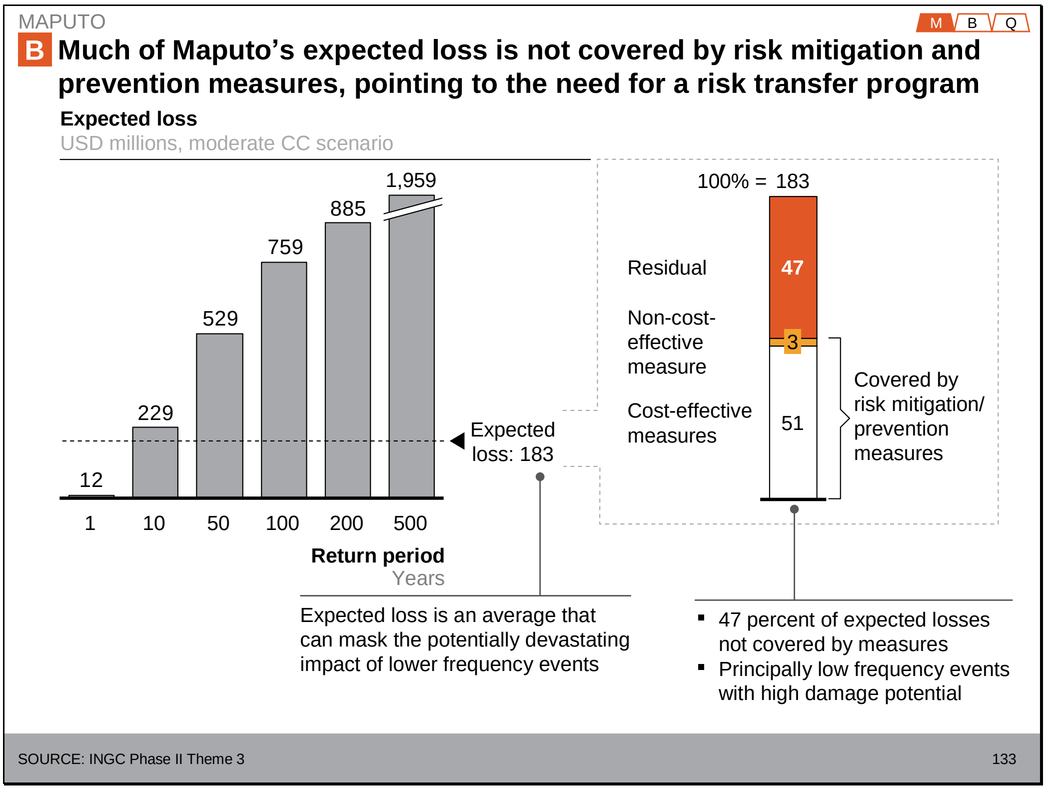
Risk transfer mechanisms should be adopted for **infrequent events**
- Government/ municipality insurance
- Private insurance

Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

SLIDE 134



MAPUTO

B Much of Maputo's expected loss is not covered by risk mitigation and prevention measures, pointing to the need for a risk transfer program

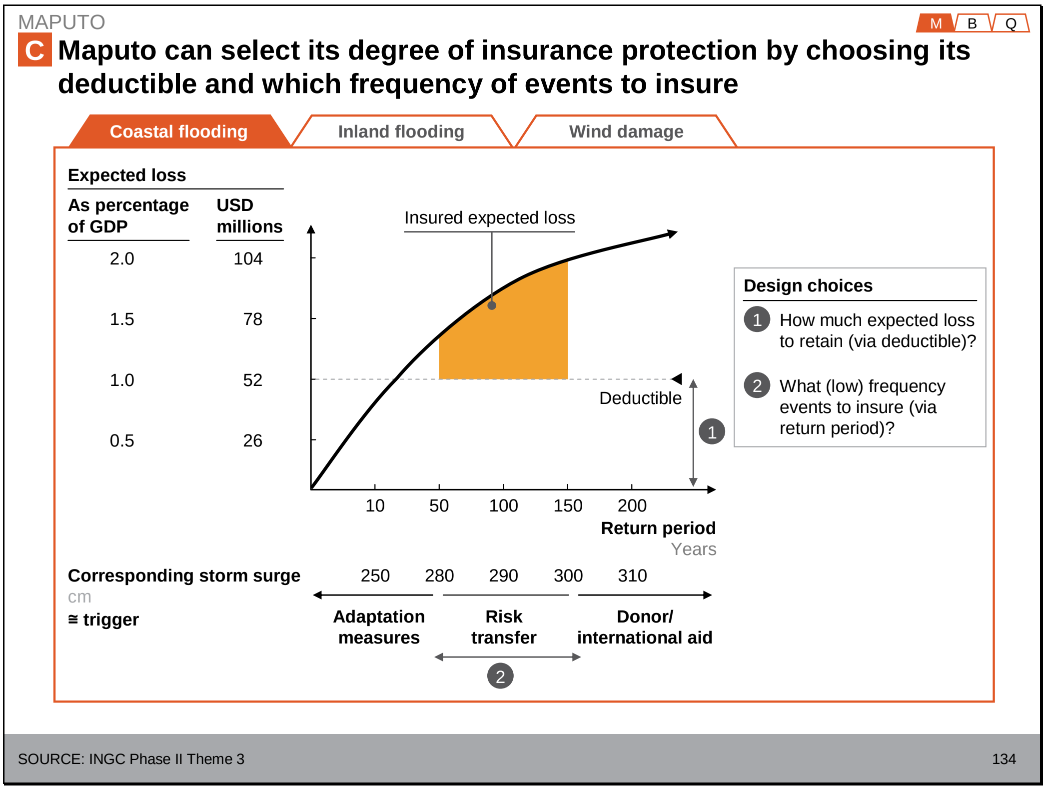
Expected loss
USD millions, moderate CC scenario

Expected loss is an average that can mask the potentially devastating impact of lower frequency events

- 47 percent of expected losses not covered by measures
- Principally low frequency events with high damage potential

SOURCE: INGC Phase II Theme 3

SLIDE 135



MAPUTO

C Maputo can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

Design choices

1. How much expected loss to retain (via deductible)?
2. What (low) frequency events to insure (via return period)?

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 135:

Possible Adaptation Responses – Insurance Program Proposal module

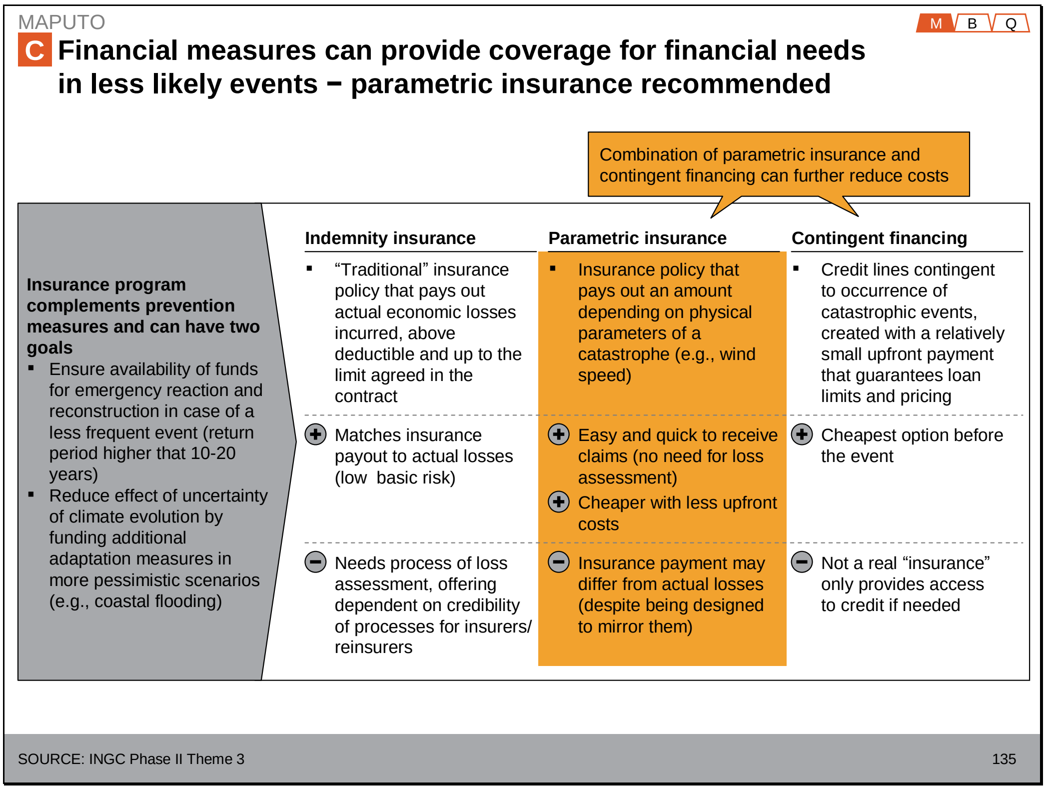
Maputo can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

This chart plots the return period of a catastrophe (how often it occurs) against the expected loss from the event.

Maputo can avoid the damages of events occurring with a relatively high frequency cost-effectively through adaptation measures. On the other end of the spectrum, there are events that occur only every several hundred years for which the municipality will need to rely on donor and international support.

In the middle of the spectrum are low probability, high impact events for which the municipality may want to transfer risk using a financial mechanism, e.g., an insurance policy. The municipality will need to determine how much risk to maintain on itself for these events, e.g., how high to set its deductible. As well, it must determine the range of events to cover with a risk transfer, e.g., events occurring ever 50 - 100 years, versus those occurring every 100 – 150 years.

SLIDE 136



MAPUTO

C Financial measures can provide coverage for financial needs in less likely events – parametric insurance recommended

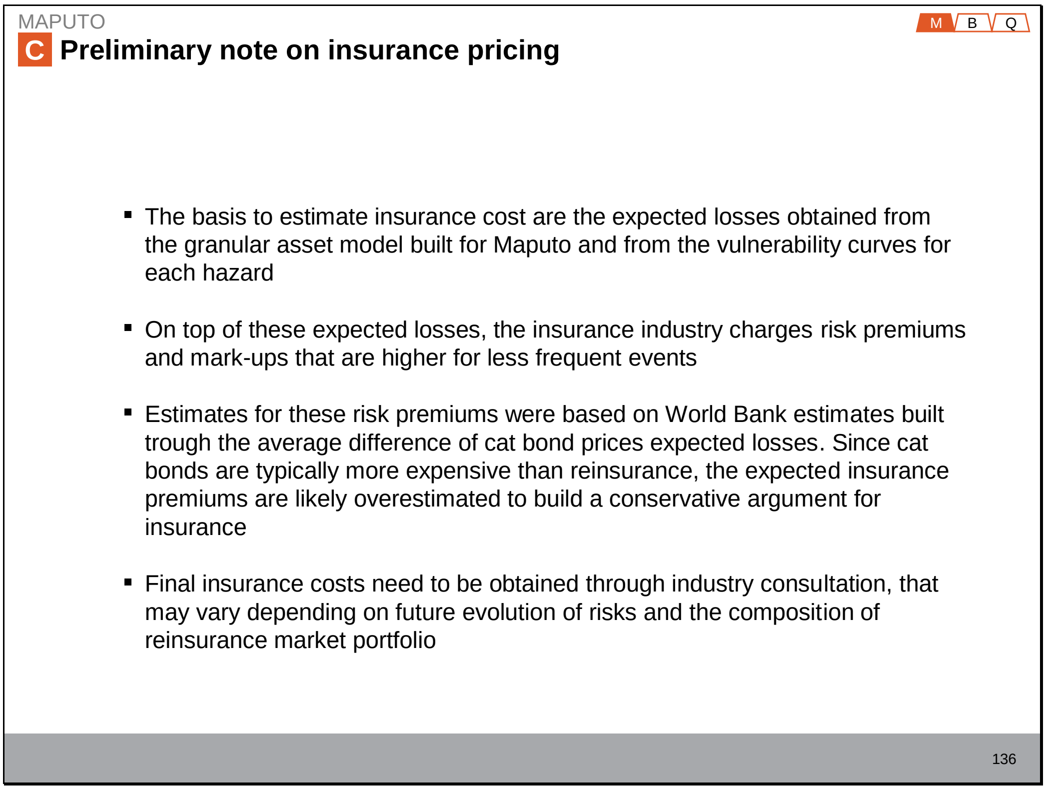
Combination of parametric insurance and contingent financing can further reduce costs

Insurance program complements prevention measures and can have two goals
- Ensure availability of funds for emergency reaction and reconstruction in case of a less frequent event (return period higher that 10-20 years)
- Reduce effect of uncertainty of climate evolution by funding additional adaptation measures in more pessimistic scenarios (e.g., coastal flooding)

Indemnity insurance	Parametric insurance	Contingent financing
▪ "Traditional" insurance policy that pays out actual economic losses incurred, above deductible and up to the limit agreed in the contract	▪ Insurance policy that pays out an amount depending on physical parameters of a catastrophe (e.g., wind speed)	▪ Credit lines contingent to occurrence of catastrophic events, created with a relatively small upfront payment that guarantees loan limits and pricing
⊕ Matches insurance payout to actual losses (low basic risk)	⊕ Easy and quick to receive claims (no need for loss assessment) ⊕ Cheaper with less upfront costs	⊕ Cheapest option before the event
⊖ Needs process of loss assessment, offering dependent on credibility of processes for insurers/ reinsurers	⊖ Insurance payment may differ from actual losses (despite being designed to mirror them)	⊖ Not a real "insurance" only provides access to credit if needed

SOURCE: INGC Phase II Theme 3

SLIDE 137

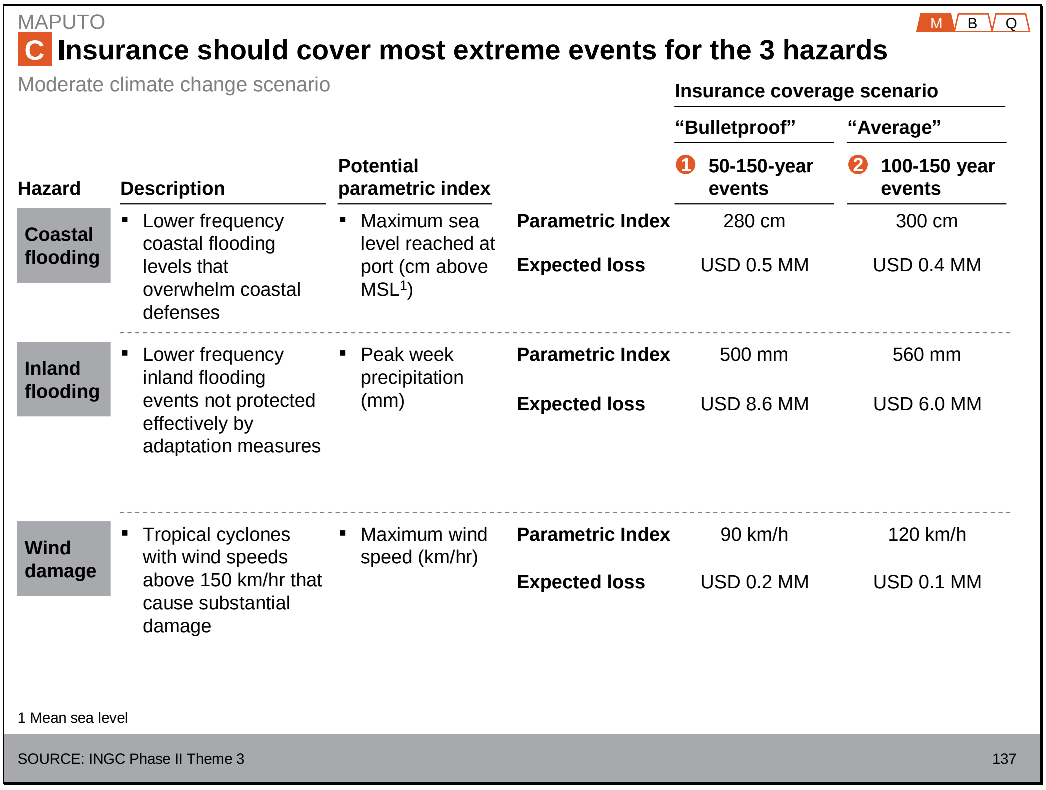


MAPUTO

C Preliminary note on insurance pricing

- The basis to estimate insurance cost are the expected losses obtained from the granular asset model built for Maputo and from the vulnerability curves for each hazard
- On top of these expected losses, the insurance industry charges risk premiums and mark-ups that are higher for less frequent events
- Estimates for these risk premiums were based on World Bank estimates built trough the average difference of cat bond prices expected losses. Since cat bonds are typically more expensive than reinsurance, the expected insurance premiums are likely overestimated to build a conservative argument for insurance
- Final insurance costs need to be obtained through industry consultation, that may vary depending on future evolution of risks and the composition of reinsurance market portfolio

SLIDE 138



MAPUTO

M | B | Q

C Insurance should cover most extreme events for the 3 hazards

Moderate climate change scenario

Hazard	Description	Potential parametric index		Insurance coverage scenario “Bulletproof” ① 50-150-year events	 “Average” ② 100-150 year events
Coastal flooding	▪ Lower frequency coastal flooding levels that overwhelm coastal defenses	▪ Maximum sea level reached at port (cm above MSL^1)	**Parametric Index**	280 cm	300 cm
			Expected loss	USD 0.5 MM	USD 0.4 MM
Inland flooding	▪ Lower frequency inland flooding events not protected effectively by adaptation measures	▪ Peak week precipitation (mm)	**Parametric Index**	500 mm	560 mm
			Expected loss	USD 8.6 MM	USD 6.0 MM
Wind damage	▪ Tropical cyclones with wind speeds above 150 km/hr that cause substantial damage	▪ Maximum wind speed (km/hr)	**Parametric Index**	90 km/h	120 km/h
			Expected loss	USD 0.2 MM	USD 0.1 MM

1 Mean sea level

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 138:

Possible Adaptation Responses – Insurance Program Proposal module

Insurance should cover most extreme events for the 3 hazards

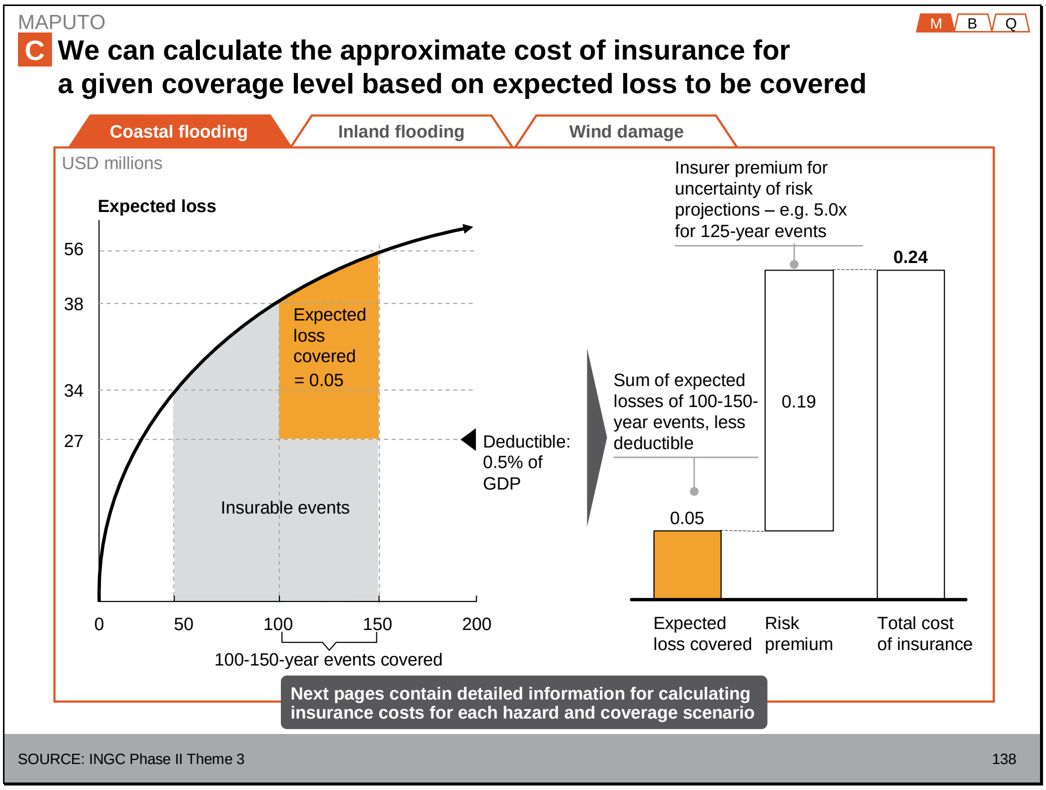
Maputo could purchase insurance to protect itself against catastrophic losses associated with three major climate events.

Two levels of insurance are described, a “bulletproof” policy level that would cover the municipality against severe events projected to occur only every 50-150 years, and an “average” policy level that would only cover the events projected to occur once every 100-150 years.

For each level of insurance and each event type, a “parametric index” is listed, meaning an event that would trigger an automatic payout of the insurance coverage. For example, for the “bulletproof” policy for coastal flooding, the insurance would pay out automatically when sea level at port reaches 280cm above MSL.

Expected losses are also listed for each policy level – the losses are greater for the bulletproof policies because, while the triggering events are on average less severe for the 50-150 year events, they also are projected to occur more often.

SLIDE 139



MAPUTO

C We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

Next pages contain detailed information for calculating insurance costs for each hazard and coverage scenario

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 139:

Possible Adaptation Responses – Insurance Program Proposal module

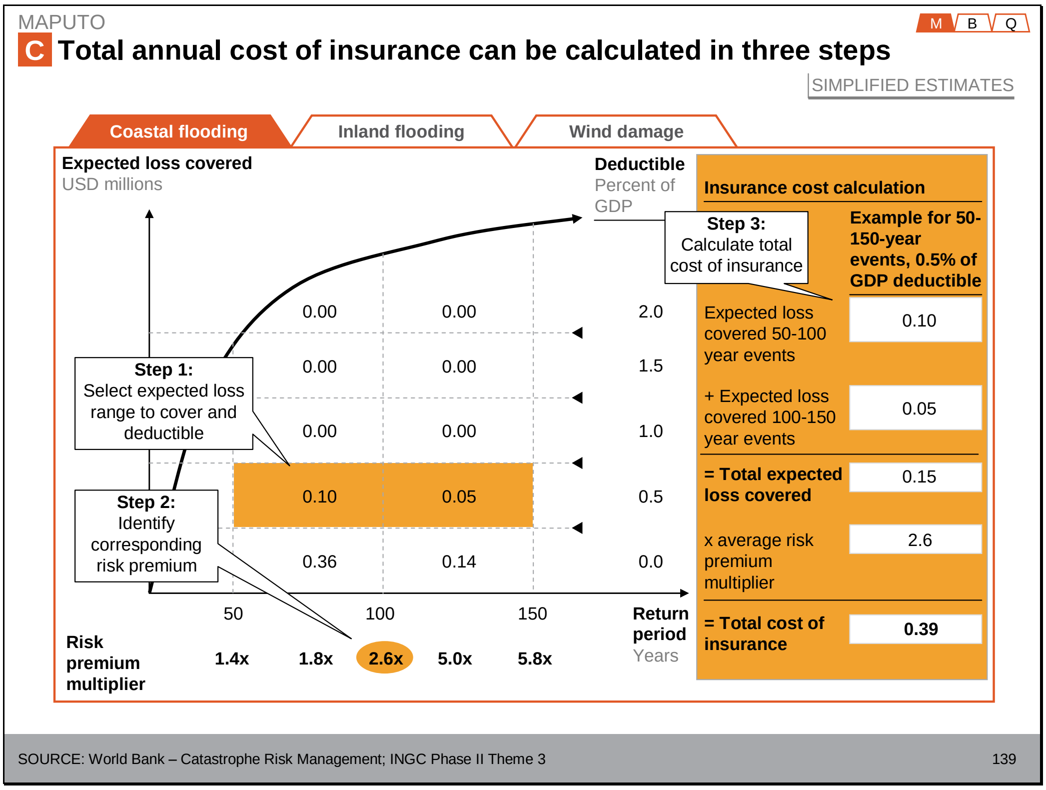
We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

First, the municipality needs to determine the range of expected loss to cover, which is a function of the range of insurable events covered by the policy, and the deductible under which the municipality will cover costs itself.

In this example, the range of events covered for coastal flooding is shown to be 100-150 year events, and the municipality has agreed to a deductible of 0.5% of it's GDP, meaning that the insurance policy will only cover losses above that level. This means that the insurer will be covering the amount between the deductible and the total expected loss for that range of events, which translates to a .05M annual insurance premium for the coverage.

Given that expected loss coverage, an estimate for the total cost of the insurance is possible. Because of the uncertainty of predictions required for these events, insurers will charge a "risk premium" that is some multiple of the expected loss covered. In this case, the risk premium multiplier for ~125 year events is ~5.0x, for a risk premium of .19 M. This is added to the expected loss covered to produced a total cost of insurance of .24 M.

SLIDE 140



MAPUTO

C Total annual cost of insurance can be calculated in three steps

M B Q

SIMPLIFIED ESTIMATES

Expected loss covered
USD millions

Deductible
Percent of GDP

0.00	0.00	2.0
0.00	0.00	1.5
0.00	0.00	1.0
0.10	0.05	0.5
0.36	0.14	0.0

Risk premium multiplier 1.4x 1.8x 2.6x 5.0x 5.8x

Step 1: Select expected loss range to cover and deductible

Step 2: Identify corresponding risk premium

Step 3: Calculate total cost of insurance

Insurance cost calculation

	Example for 50-150-year events, 0.5% of GDP deductible
Expected loss covered 50-100 year events	0.10
+ Expected loss covered 100-150 year events	0.05
= Total expected loss covered	0.15
x average risk premium multiplier	2.6
= Total cost of insurance	**0.39**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

NOTES FOR SLIDE 140:

Possible Adaptation Responses – Insurance Program Proposal module

Total annual cost of insurance can be calculated in three steps

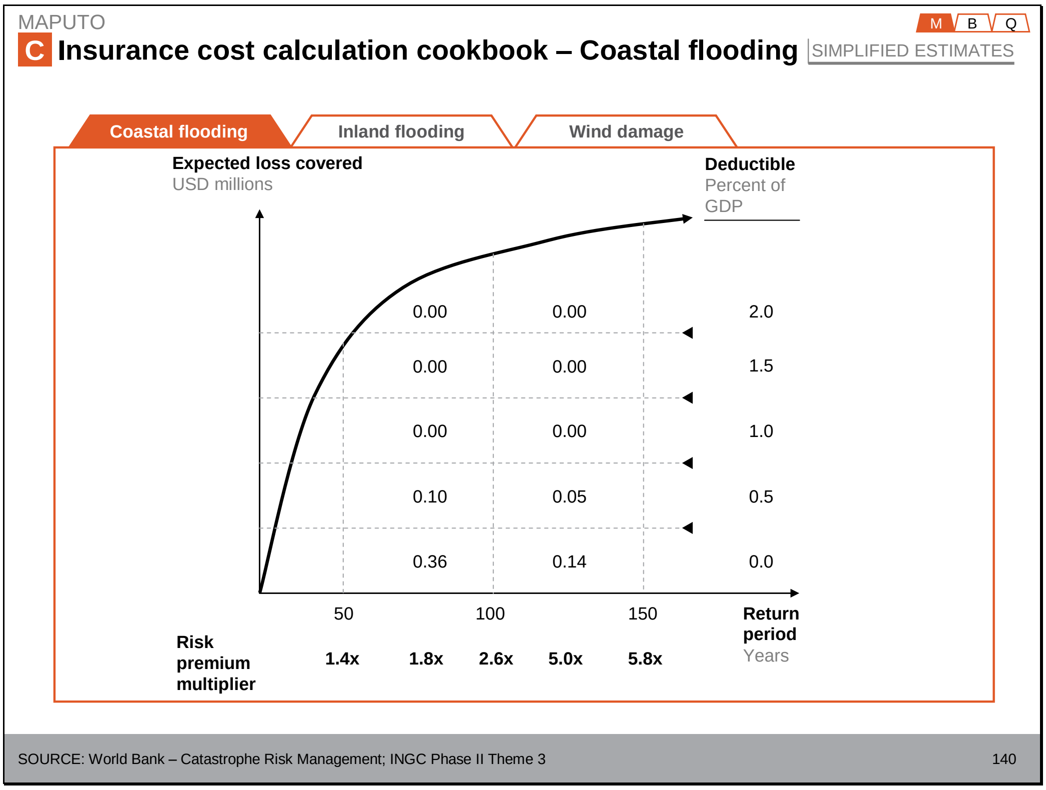
This page displays a more detailed explanation of the total cost of insurance concept from the previous page.

The first step shown is to select a range of events to cover, and a deductible under which the municipality will cover itself.

The second step is to identify the risk premium multiplier that corresponds with that coverage range.

The third step is to calculate the total cost of insurance by multiplying the total expected loss covered by the risk premium multiplier to get the risk premium. The total expected loss covered and the risk premium are then added together to generate the total cost of insurance.

SLIDE 141



MAPUTO

C Insurance cost calculation cookbook – Coastal flooding SIMPLIFIED ESTIMATES

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

NOTES FOR SLIDE 141:

Possible Adaptation Responses – Insurance Program Proposal module

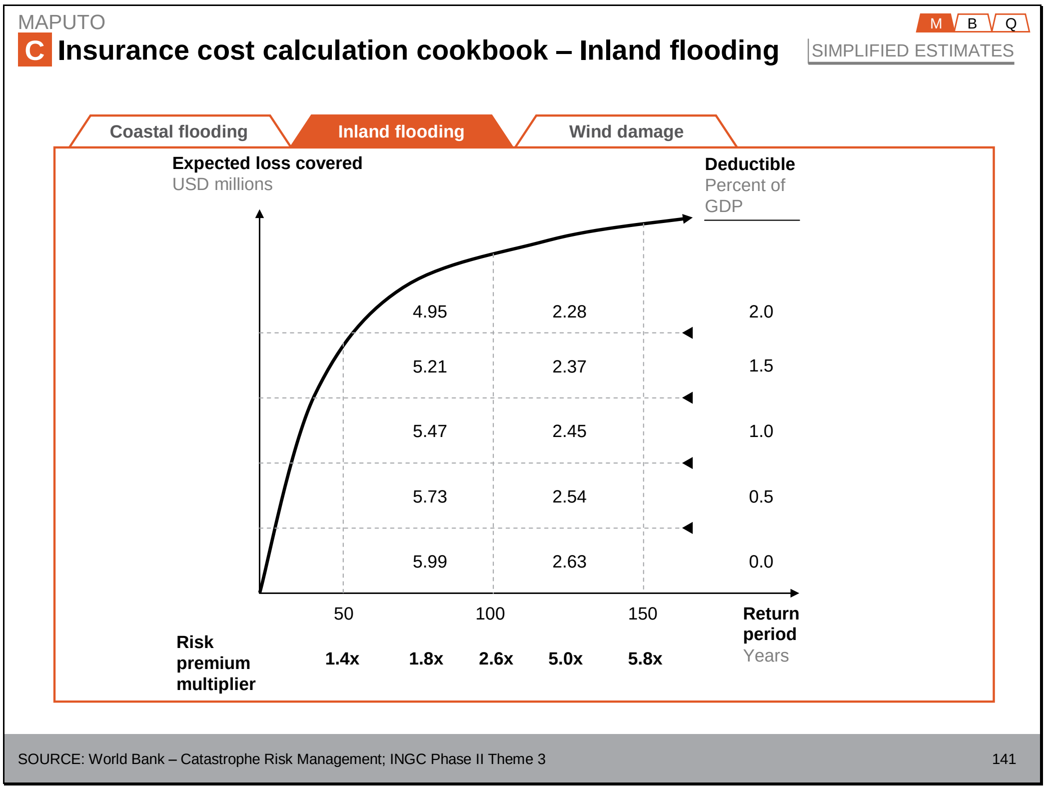
Insurance cost calculation cookbook – Coastal flooding

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Maputo in considering it's likely insurance cost for coastal flooding.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 142



MAPUTO

C Insurance cost calculation cookbook – Inland flooding

4.95	2.28	2.0
5.21	2.37	1.5
5.47	2.45	1.0
5.73	2.54	0.5
5.99	2.63	0.0

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

141

NOTES FOR SLIDE 142:

Possible Adaptation Responses – Insurance Program Proposal module

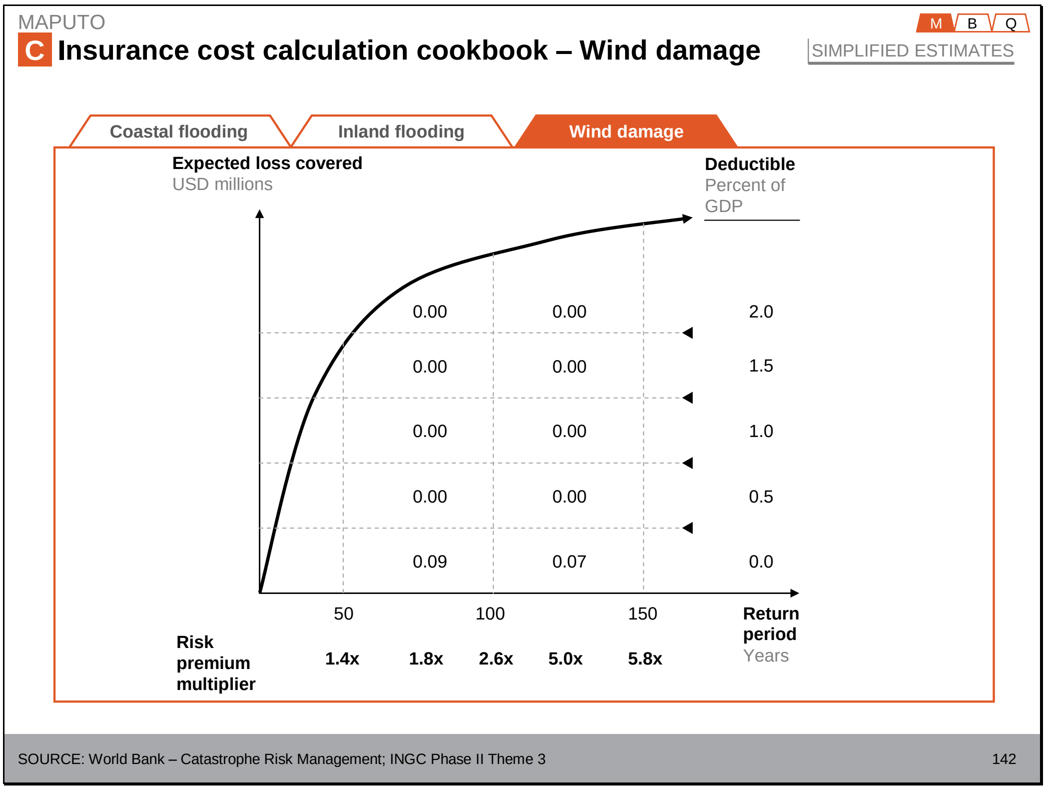
Insurance cost calculation cookbook – Inland flooding

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Maputo in considering it's likely insurance cost for inland flooding.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 143



MAPUTO

C Insurance cost calculation cookbook – Wind damage

0.00	0.00	2.0
0.00	0.00	1.5
0.00	0.00	1.0
0.00	0.00	0.5
0.09	0.07	0.0

Risk premium multiplier	**1.4x**	**1.8x**	**2.6x**	**5.0x**	**5.8x**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

NOTES FOR SLIDE 143:

Possible Adaptation Responses – Insurance Program Proposal module

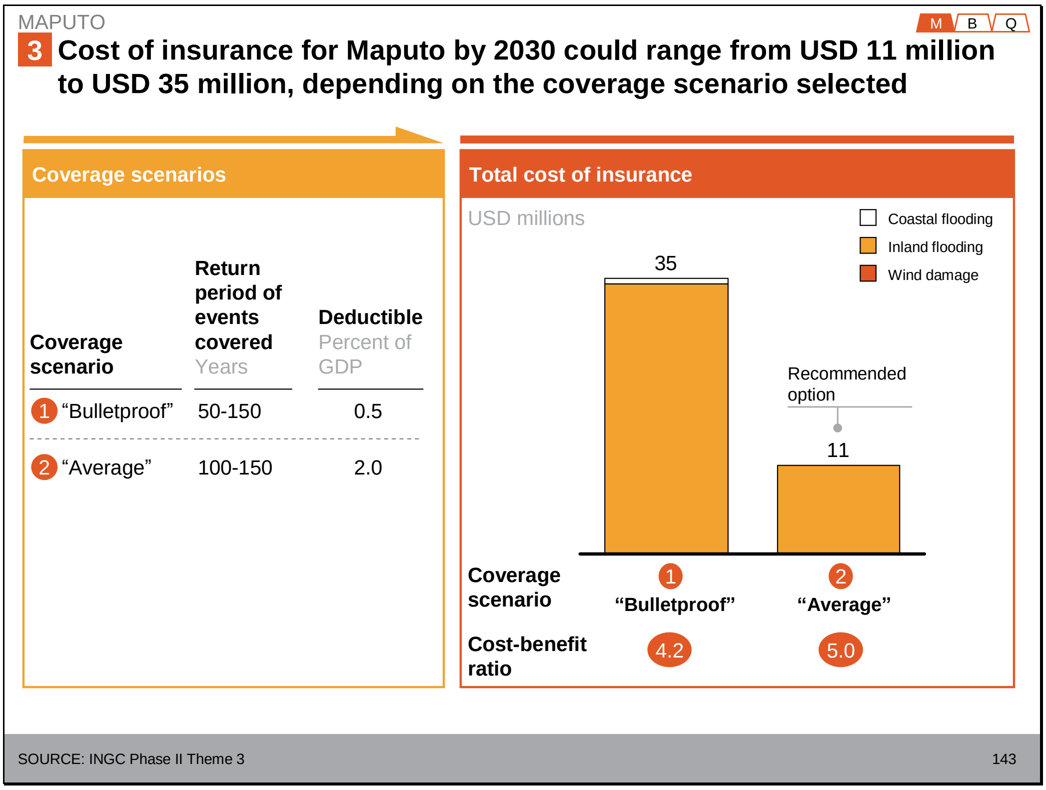
Insurance cost calculation cookbook – Wind damage

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Maputo in considering it's likely insurance cost for wind damage.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 144



MAPUTO

3 Cost of insurance for Maputo by 2030 could range from USD 11 million to USD 35 million, depending on the coverage scenario selected

Coverage scenarios

Coverage scenario	**Return period of events covered** Years	**Deductible** Percent of GDP
1 "Bulletproof"	50-150	0.5
2 "Average"	100-150	2.0

Total cost of insurance

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 144:

Possible Adaptation Responses – Insurance Program Proposal module

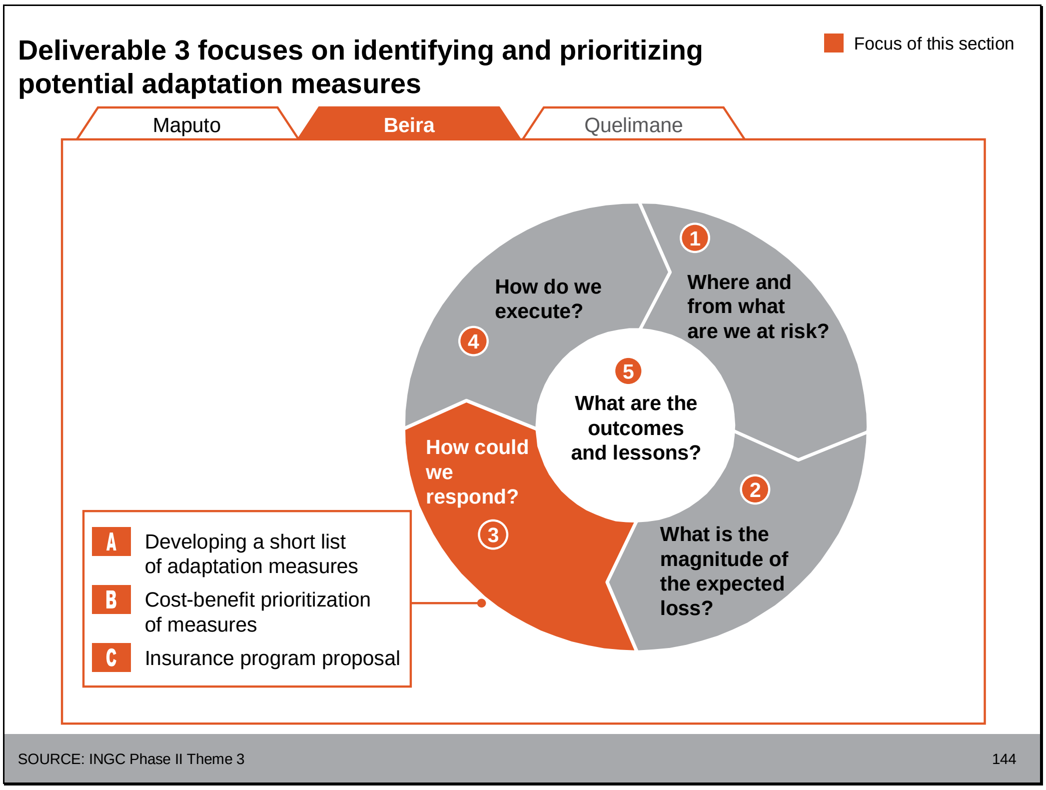
Cost of insurance for Maputo by 2030 could range from USD 11 million to USD 35 million, depending on the coverage scenario selected

Two different coverage scenarios are described here. The first (the "bulletproof") has a wider range of events covered (50-150 year events), and a lower deductible – 0.5% of GDP. The second (the "average") chooses a narrower range of events to cover (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks for each hazard type on the previous pages to calculate the total cost of insurance, the annual costs were identified and added in the bars on the right for each scenario.

Lastly, the Cost-benefit ratios were calculated for each insurance policy, showing the amount paid for the policy divided by the estimated payouts. Because of the large risk premiums for these policies, the cost benefit ratios for both coverage scenarios are quite poor (meaning much greater than 1), particularly when compared with other direct prevention measures.

SLIDE 145



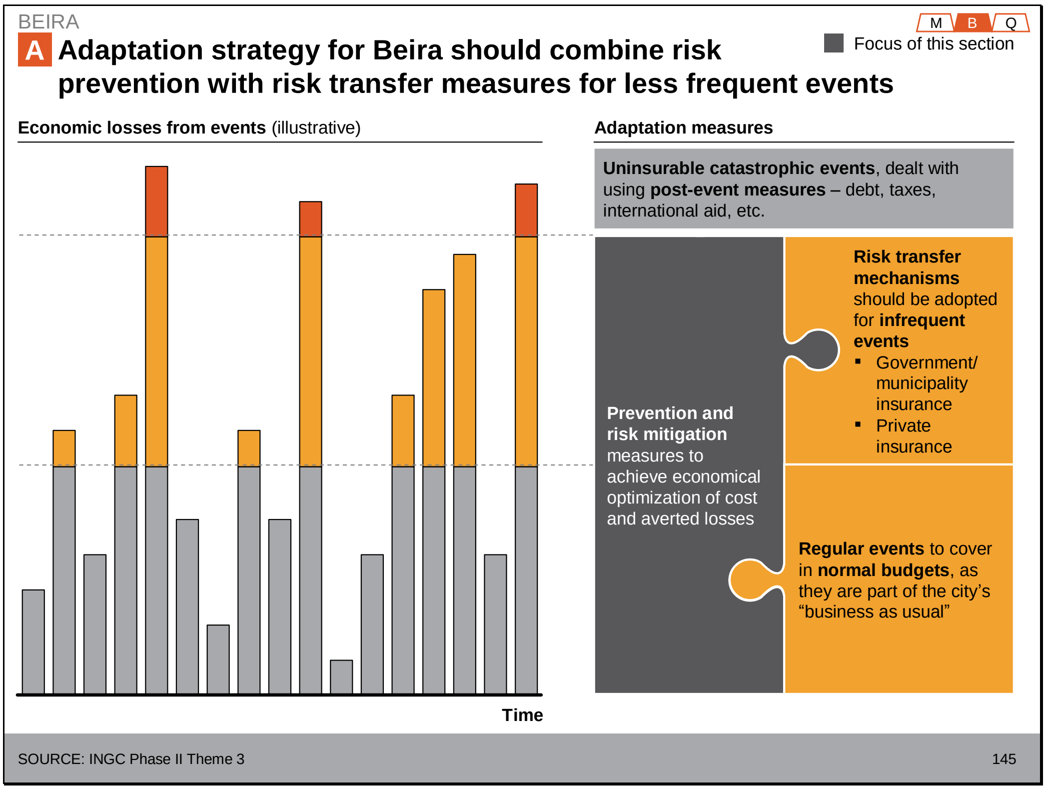
🟧 Focus of this section

Deliverable 3 focuses on identifying and prioritizing potential adaptation measures

- **A** Developing a short list of adaptation measures
- **B** Cost-benefit prioritization of measures
- **C** Insurance program proposal

SOURCE: INGC Phase II Theme 3

SLIDE 146



BEIRA

■ Focus of this section

A Adaptation strategy for Beira should combine risk prevention with risk transfer measures for less frequent events

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

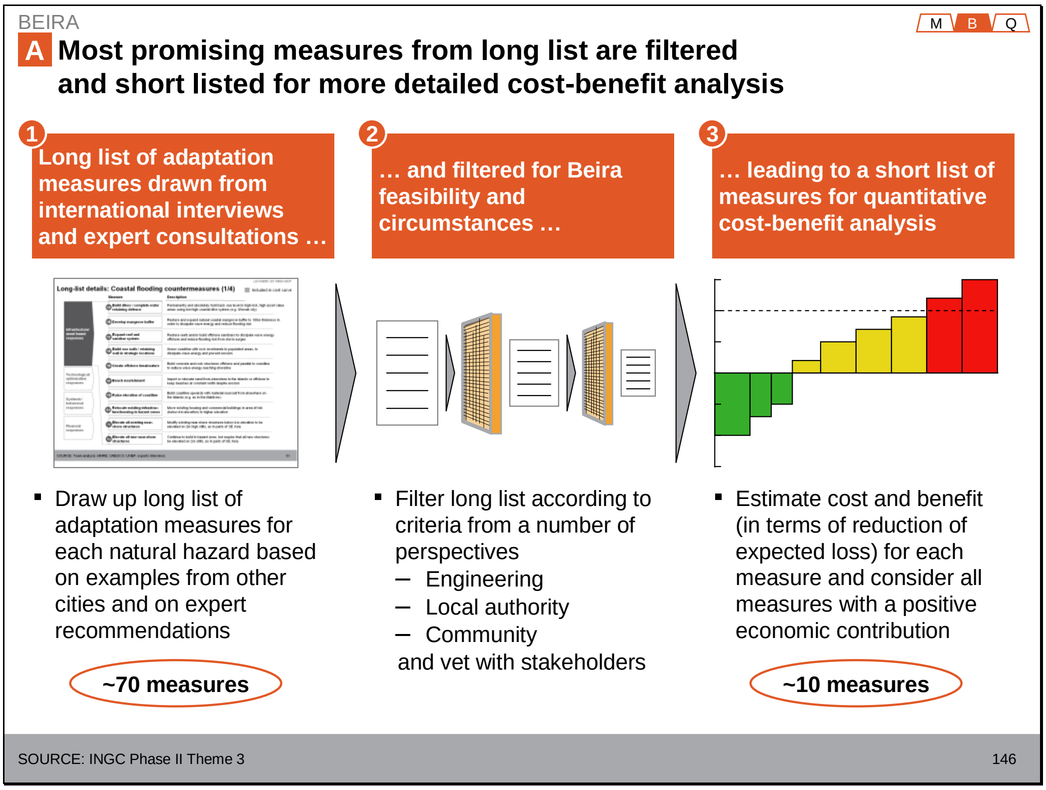
Risk transfer mechanisms should be adopted for **infrequent events**

- Government/ municipality insurance
- Private insurance

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

SLIDE 147



BEIRA

M B Q

A Most promising measures from long list are filtered and short listed for more detailed cost-benefit analysis

① **Long list of adaptation measures drawn from international interviews and expert consultations …**

- Draw up long list of adaptation measures for each natural hazard based on examples from other cities and on expert recommendations

~70 measures

② **… and filtered for Beira feasibility and circumstances …**

- Filter long list according to criteria from a number of perspectives
  - Engineering
  - Local authority
  - Community

  and vet with stakeholders

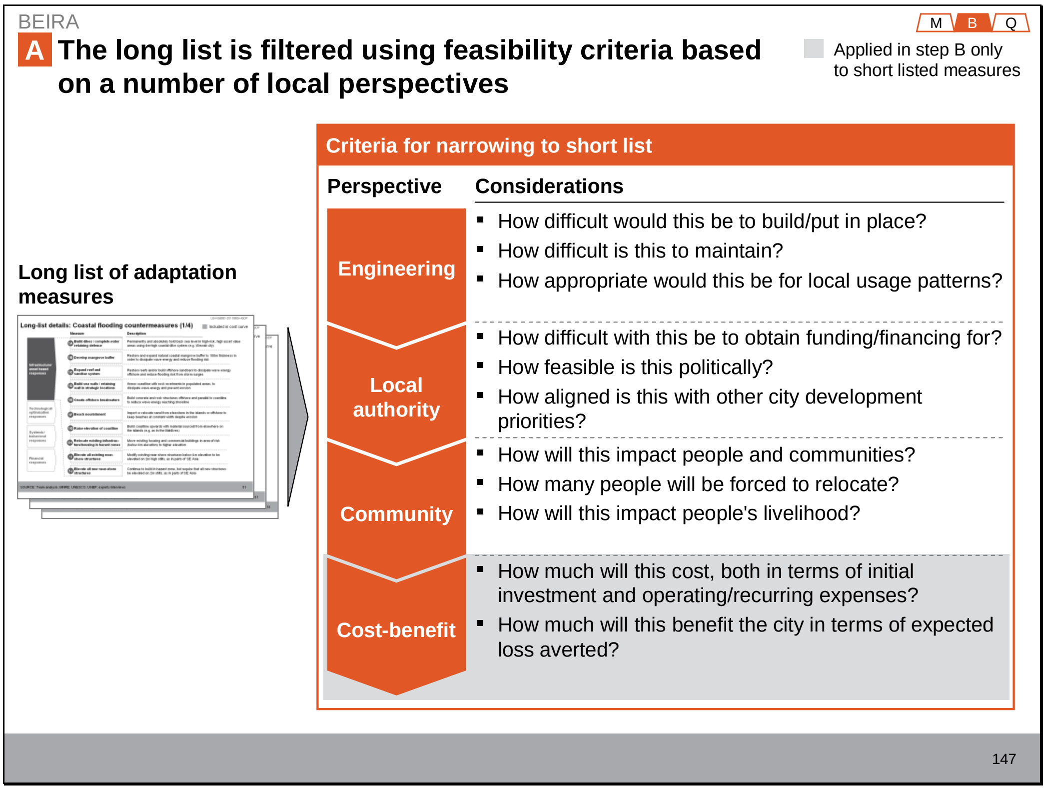
③ **… leading to a short list of measures for quantitative cost-benefit analysis**

- Estimate cost and benefit (in terms of reduction of expected loss) for each measure and consider all measures with a positive economic contribution

~10 measures

SOURCE: INGC Phase II Theme 3

SLIDE 148



BEIRA

M B Q

A The long list is filtered using feasibility criteria based on a number of local perspectives

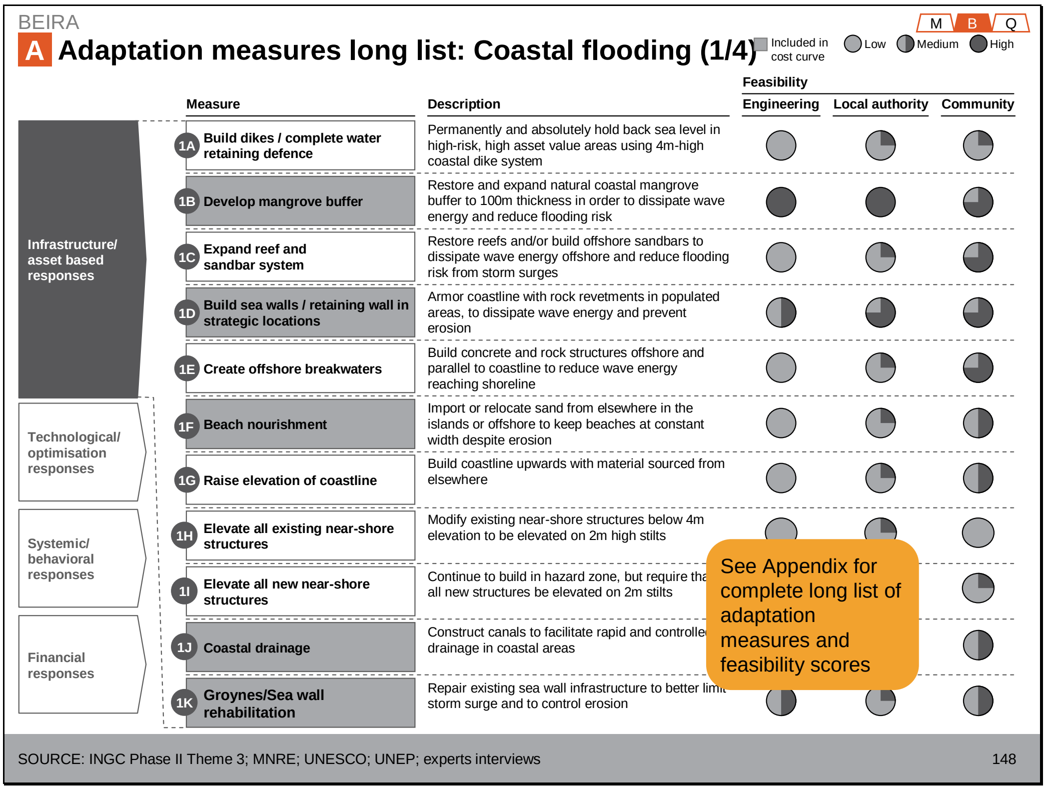
▨ Applied in step B only to short listed measures

Long list of adaptation measures

Criteria for narrowing to short list

Perspective	Considerations
Engineering	How difficult would this be to build/put in place? How difficult is this to maintain? How appropriate would this be for local usage patterns?
Local authority	How difficult with this be to obtain funding/financing for? How feasible is this politically? How aligned is this with other city development priorities?
Community	How will this impact people and communities? How many people will be forced to relocate? How will this impact people's livelihood?
Cost-benefit	How much will this cost, both in terms of initial investment and operating/recurring expenses? How much will this benefit the city in terms of expected loss averted?

SLIDE 149



M B Q

BEIRA

A Adaptation measures long list: Coastal flooding (1/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

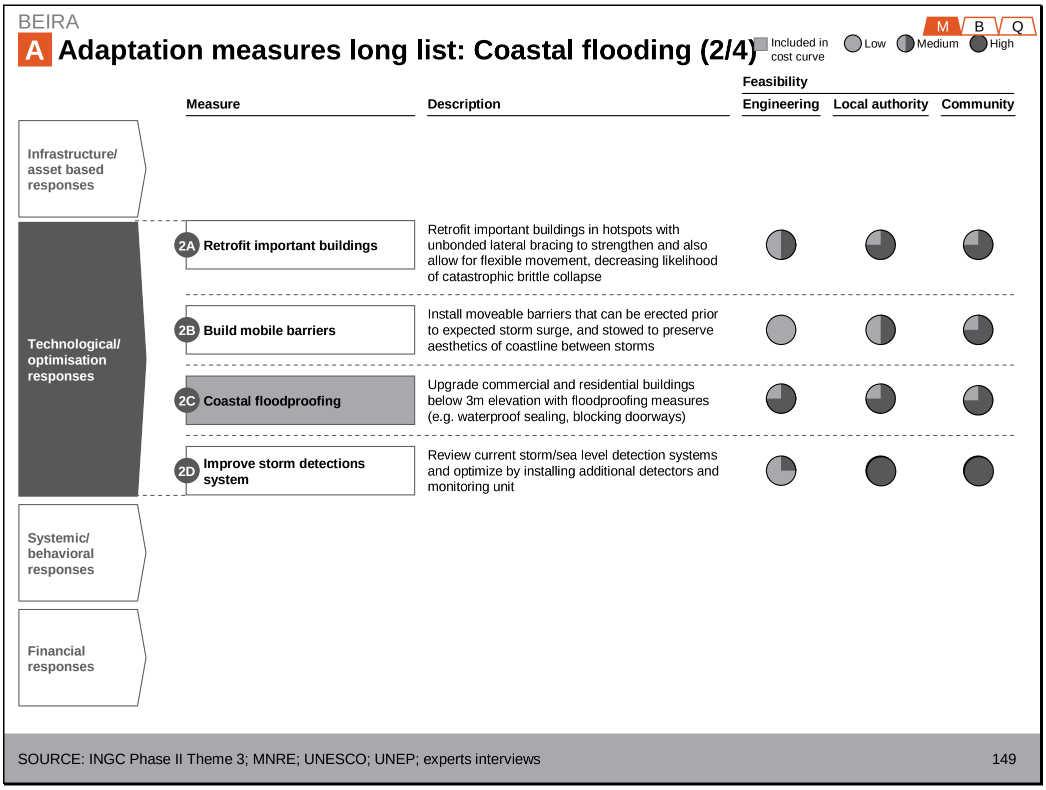
		Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Infrastructure/ asset based responses	1A	Build dikes / complete water retaining defence	Permanently and absolutely hold back sea level in high-risk, high asset value areas using 4m-high coastal dike system	○	◔	◔
	1B	▨ Develop mangrove buffer	Restore and expand natural coastal mangrove buffer to 100m thickness in order to dissipate wave energy and reduce flooding risk	●	●	◕
	1C	Expand reef and sandbar system	Restore reefs and/or build offshore sandbars to dissipate wave energy offshore and reduce flooding risk from storm surges	○	◔	◕
	1D	▨ Build sea walls / retaining wall in strategic locations	Armor coastline with rock revetments in populated areas, to dissipate wave energy and prevent erosion	◑	◕	◕
	1E	Create offshore breakwaters	Build concrete and rock structures offshore and parallel to coastline to reduce wave energy reaching shoreline	○	◔	◕
	1F	▨ Beach nourishment	Import or relocate sand from elsewhere in the islands or offshore to keep beaches at constant width despite erosion	○	◔	◑
	1G	Raise elevation of coastline	Build coastline upwards with material sourced from elsewhere	○	◔	◑
	1H	Elevate all existing near-shore structures	Modify existing near-shore structures below 4m elevation to be elevated on 2m high stilts	○	◔	○
	1I	Elevate all new near-shore structures	Continue to build in hazard zone, but require tha all new structures be elevated on 2m stilts			◔
	1J	▨ Coastal drainage	Construct canals to facilitate rapid and controlle drainage in coastal areas			◑
	1K	▨ Groynes/Sea wall rehabilitation	Repair existing sea wall infrastructure to better limi storm surge and to control erosion	◑	◔	◑
Technological/ optimisation responses						
Systemic/ behavioral responses						
Financial responses						

See Appendix for complete long list of adaptation measures and feasibility scores

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

148

SLIDE 150



M B Q

BEIRA

A Adaptation measures long list: Coastal flooding (2/4)

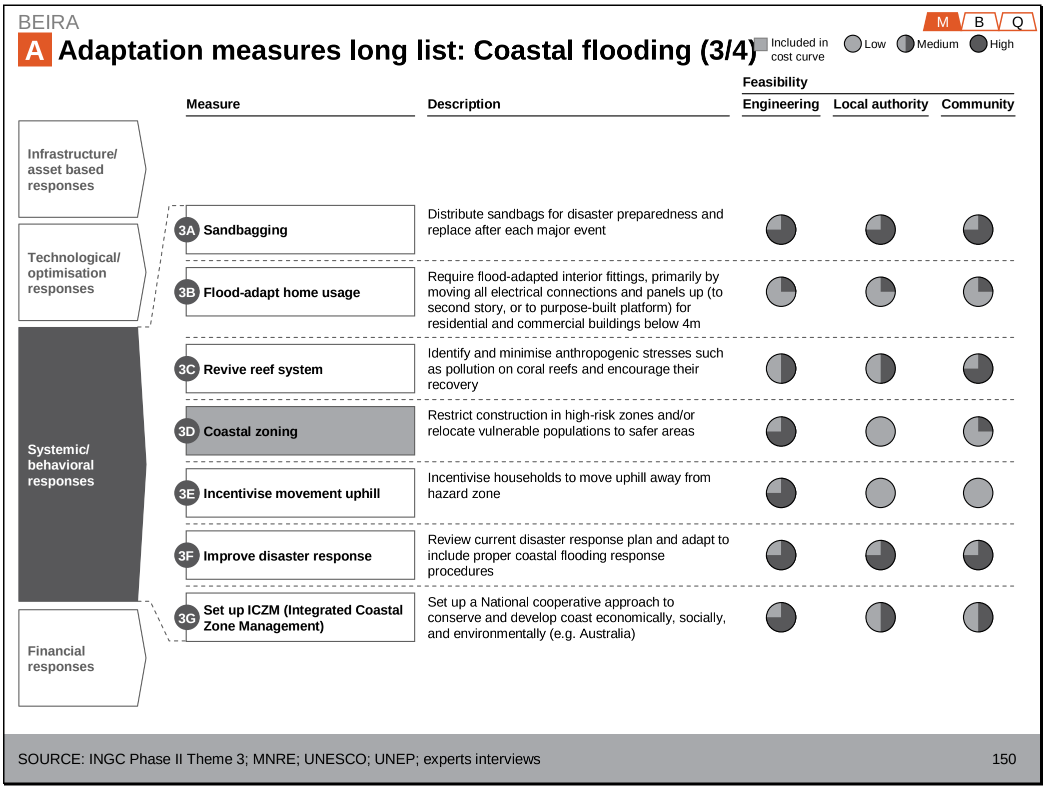
▨ Included in cost curve ○ Low ◑ Medium ● High

		Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Infrastructure/ asset based responses						
Technological/ optimisation responses	2A	Retrofit important buildings	Retrofit important buildings in hotspots with unbonded lateral bracing to strengthen and also allow for flexible movement, decreasing likelihood of catastrophic brittle collapse	◑	◕	◕
	2B	Build mobile barriers	Install moveable barriers that can be erected prior to expected storm surge, and stowed to preserve aesthetics of coastline between storms	○	◑	◕
	2C	▨ Coastal floodproofing	Upgrade commercial and residential buildings below 3m elevation with floodproofing measures (e.g. waterproof sealing, blocking doorways)	◕	◕	◕
	2D	Improve storm detections system	Review current storm/sea level detection systems and optimize by installing additional detectors and monitoring unit	◔	●	●
Systemic/ behavioral responses						
Financial responses						

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

149

SLIDE 151



BEIRA

M B Q

A Adaptation measures long list: Coastal flooding (3/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

Systemic/ behavioral responses

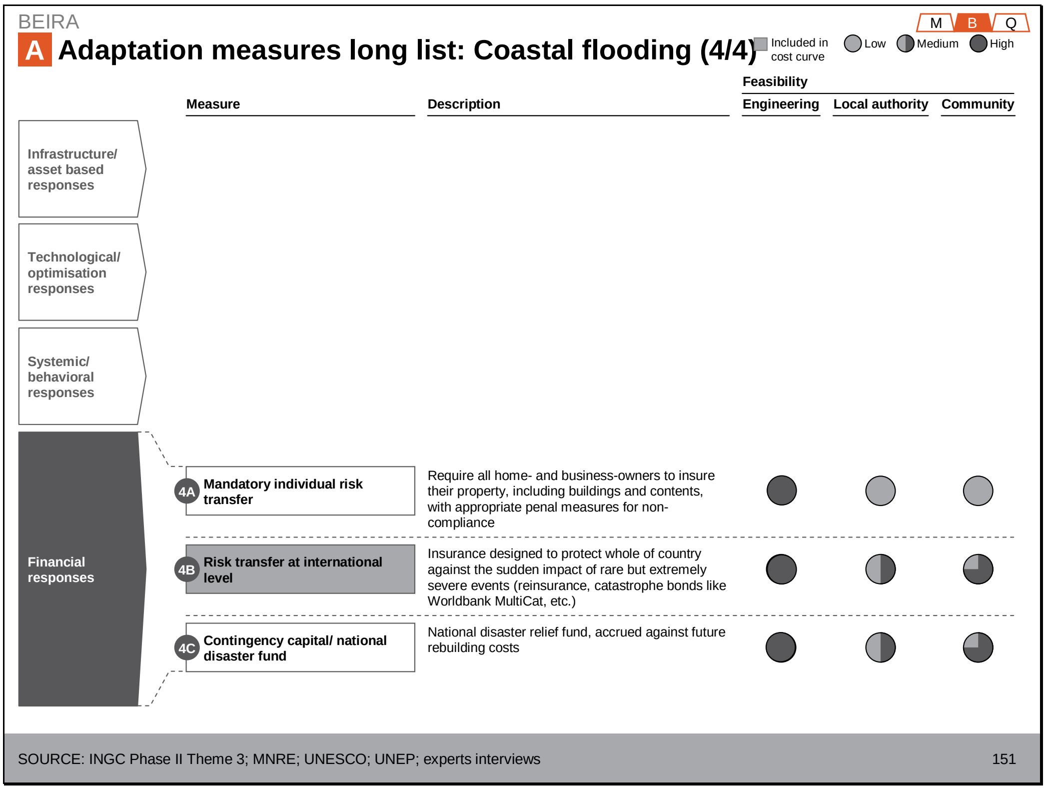
Financial responses

	Measure	Description	Feasibility Engineering	Local authority	Community
3A	Sandbagging	Distribute sandbags for disaster preparedness and replace after each major event	◕	◕	◕
3B	Flood-adapt home usage	Require flood-adapted interior fittings, primarily by moving all electrical connections and panels up (to second story, or to purpose-built platform) for residential and commercial buildings below 4m	◔	◔	◔
3C	Revive reef system	Identify and minimise anthropogenic stresses such as pollution on coral reefs and encourage their recovery	◑	◑	◕
3D	▨ Coastal zoning	Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	◕	○	◔
3E	Incentivise movement uphill	Incentivise households to move uphill away from hazard zone	◕	○	○
3F	Improve disaster response	Review current disaster response plan and adapt to include proper coastal flooding response procedures	◕	◕	◕
3G	Set up ICZM (Integrated Coastal Zone Management)	Set up a National cooperative approach to conserve and develop coast economically, socially, and environmentally (e.g. Australia)	◕	◑	◑

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

150

SLIDE 152



BEIRA

M B Q

A Adaptation measures long list: Coastal flooding (4/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

Systemic/ behavioral responses

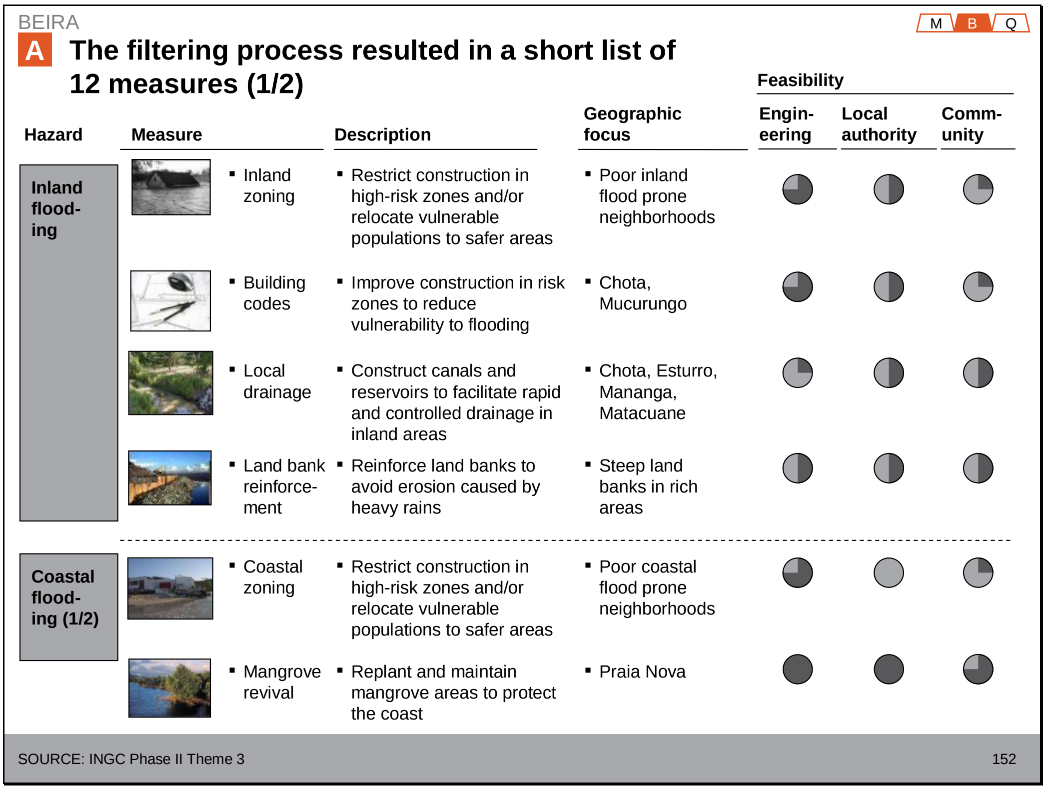
Financial responses

	Measure	Description	Feasibility Engineering	Local authority	Community
4A	Mandatory individual risk transfer	Require all home- and business-owners to insure their property, including buildings and contents, with appropriate penal measures for non-compliance	●	○	○
4B	▨ Risk transfer at international level	Insurance designed to protect whole of country against the sudden impact of rare but extremely severe events (reinsurance, catastrophe bonds like Worldbank MultiCat, etc.)	●	◑	◕
4C	Contingency capital/ national disaster fund	National disaster relief fund, accrued against future rebuilding costs	●	◑	◕

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

151

SLIDE 153



BEIRA

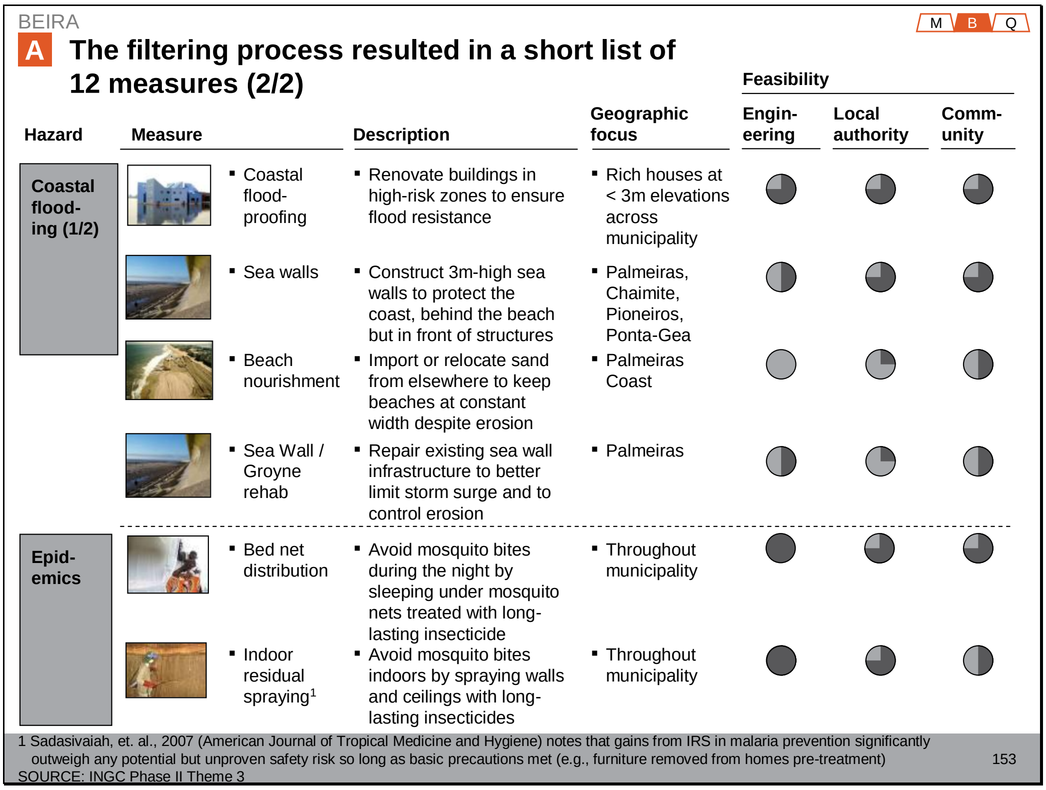
M B Q

A The filtering process resulted in a short list of 12 measures (1/2)

Hazard	Measure	Description	Geographic focus	Feasibility Engineering	Feasibility Local authority	Feasibility Community
Inland flooding	▪ Inland zoning	▪ Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	▪ Poor inland flood prone neighborhoods	◕	◑	◔
	▪ Building codes	▪ Improve construction in risk zones to reduce vulnerability to flooding	▪ Chota, Mucurungo	◕	◑	◔
	▪ Local drainage	▪ Construct canals and reservoirs to facilitate rapid and controlled drainage in inland areas	▪ Chota, Esturro, Mananga, Matacuane	◔	◑	◑
	▪ Land bank reinforcement	▪ Reinforce land banks to avoid erosion caused by heavy rains	▪ Steep land banks in rich areas	◑	◑	◑
Coastal flooding (1/2)	▪ Coastal zoning	▪ Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	▪ Poor coastal flood prone neighborhoods	◕	○	◔
	▪ Mangrove revival	▪ Replant and maintain mangrove areas to protect the coast	▪ Praia Nova	●	●	◕

SOURCE: INGC Phase II Theme 3

SLIDE 154



BEIRA

M B Q

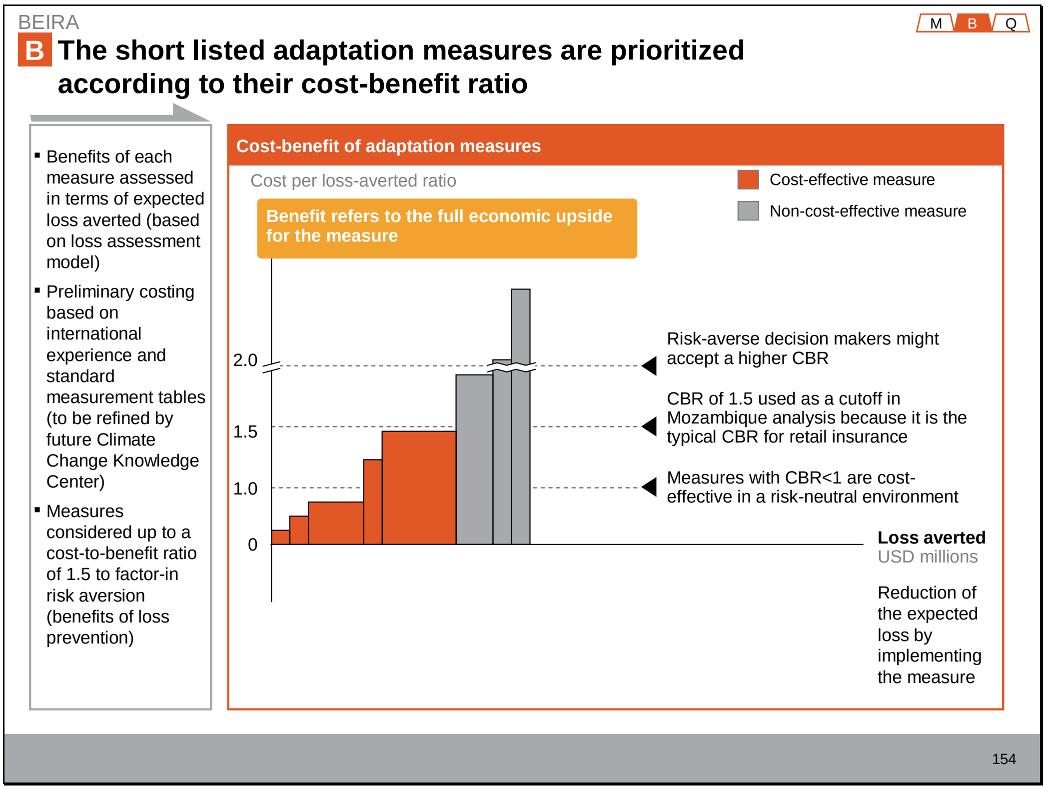
A The filtering process resulted in a short list of 12 measures (2/2)

Hazard	Measure	Description	Geographic focus	Feasibility Engineering	Feasibility Local authority	Feasibility Community
Coastal flooding (1/2)	▪ Coastal flood-proofing	▪ Renovate buildings in high-risk zones to ensure flood resistance	▪ Rich houses at < 3m elevations across municipality	◕	◕	◕
	▪ Sea walls	▪ Construct 3m-high sea walls to protect the coast, behind the beach but in front of structures	▪ Palmeiras, Chaimite, Pioneiros, Ponta-Gea	◑	◕	◕
	▪ Beach nourishment	▪ Import or relocate sand from elsewhere to keep beaches at constant width despite erosion	▪ Palmeiras Coast	○	◔	◑
	▪ Sea Wall / Groyne rehab	▪ Repair existing sea wall infrastructure to better limit storm surge and to control erosion	▪ Palmeiras	◑	◔	◑
Epidemics	▪ Bed net distribution	▪ Avoid mosquito bites during the night by sleeping under mosquito nets treated with long-lasting insecticide	▪ Throughout municipality	●	◕	◕
	▪ Indoor residual spraying[1]	▪ Avoid mosquito bites indoors by spraying walls and ceilings with long-lasting insecticides	▪ Throughout municipality	●	◕	◑

[1] Sadasivaiah, et. al., 2007 (American Journal of Tropical Medicine and Hygiene) notes that gains from IRS in malaria prevention significantly outweigh any potential but unproven safety risk so long as basic precautions met (e.g., furniture removed from homes pre-treatment)

SOURCE: INGC Phase II Theme 3

SLIDE 155



BEIRA

B The short listed adaptation measures are prioritized according to their cost-benefit ratio

- Benefits of each measure assessed in terms of expected loss averted (based on loss assessment model)
- Preliminary costing based on international experience and standard measurement tables (to be refined by future Climate Change Knowledge Center)
- Measures considered up to a cost-to-benefit ratio of 1.5 to factor-in risk aversion (benefits of loss prevention)

Cost-benefit of adaptation measures

Cost per loss-averted ratio

🟥 Cost-effective measure
▨ Non-cost-effective measure

Benefit refers to the full economic upside for the measure

Risk-averse decision makers might accept a higher CBR

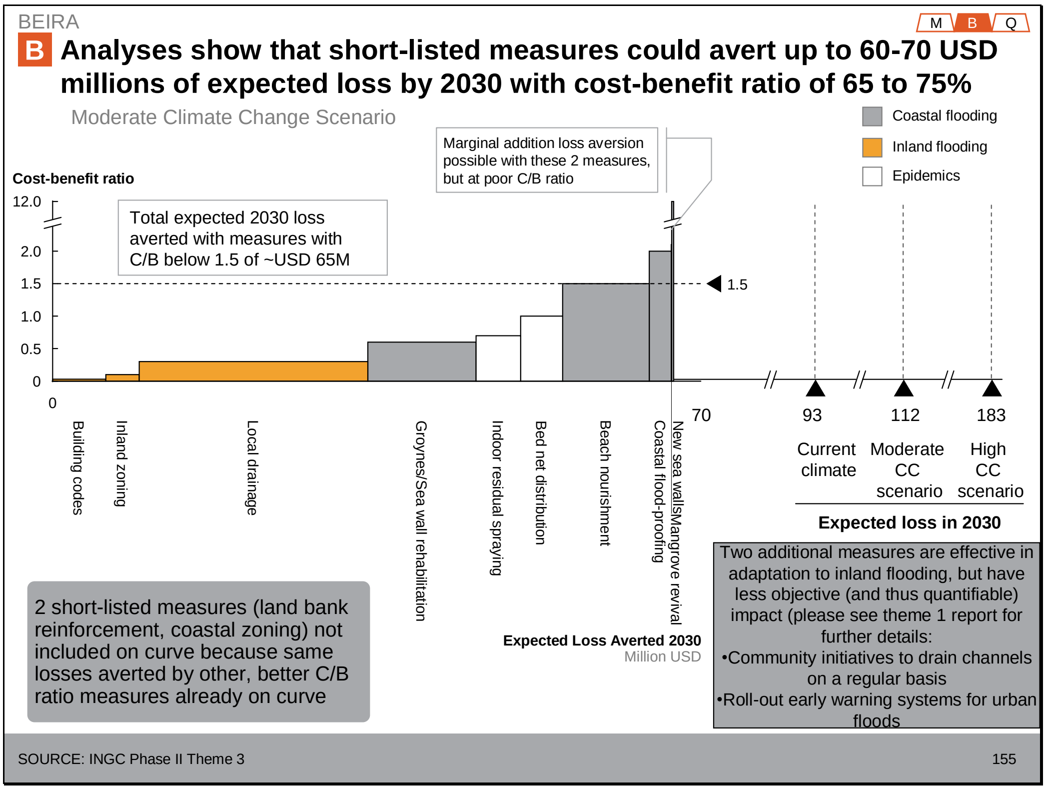
CBR of 1.5 used as a cutoff in Mozambique analysis because it is the typical CBR for retail insurance

Measures with CBR<1 are cost-effective in a risk-neutral environment

Loss averted
USD millions

Reduction of the expected loss by implementing the measure

SLIDE 156



BEIRA

B Analyses show that short-listed measures could avert up to 60-70 USD millions of expected loss by 2030 with cost-benefit ratio of 65 to 75%

Moderate Climate Change Scenario

▨ Coastal flooding
🟧 Inland flooding
☐ Epidemics

Marginal addition loss aversion possible with these 2 measures, but at poor C/B ratio

Total expected 2030 loss averted with measures with C/B below 1.5 of ~USD 65M

2 short-listed measures (land bank reinforcement, coastal zoning) not included on curve because same losses averted by other, better C/B ratio measures already on curve

Two additional measures are effective in adaptation to inland flooding, but have less objective (and thus quantifiable) impact (please see theme 1 report for further details:
•Community initiatives to drain channels on a regular basis
•Roll-out early warning systems for urban floods

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 156:

Response measures – Shortlist of adaptation measures module

Analyses show that short-listed measures could avert up to 60-70 USD millions of expected loss by 2030 with cost-benefit ration of 65 to 75%

This "cost curve" charts the most cost effective actions that Beira could take in order avoid climate-caused losses by 2030.

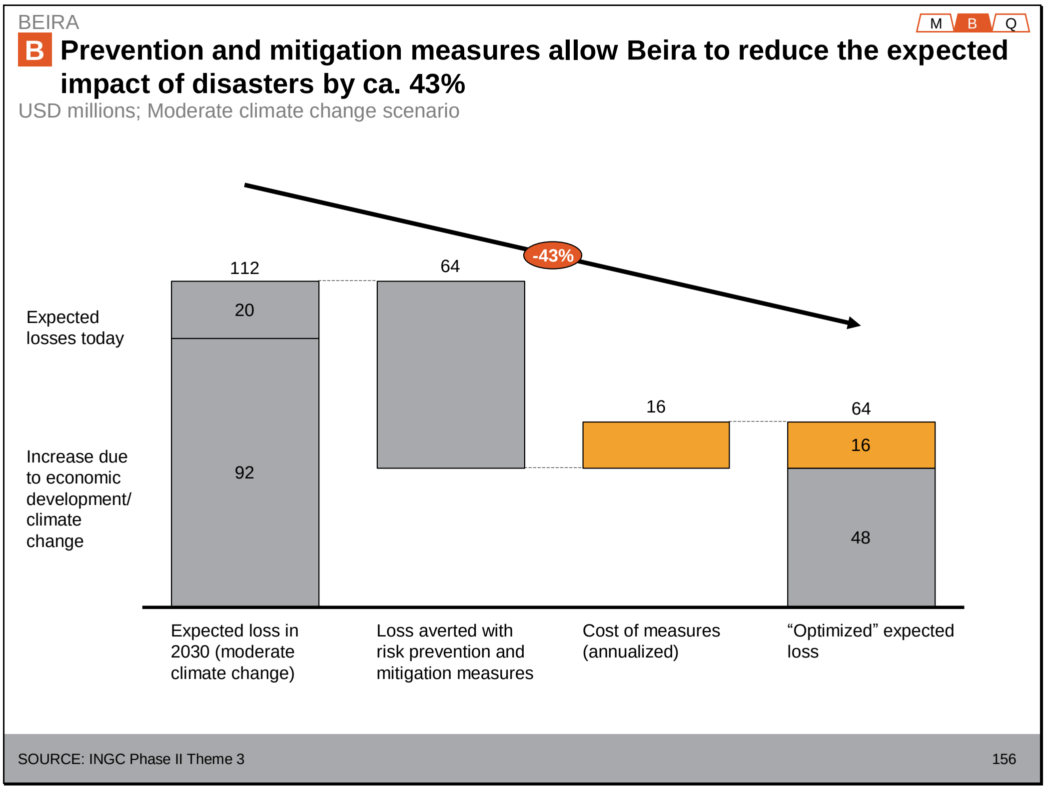
The x axis shows the expected losses that will be incurred by Beira by 2030. The three lines all the way to the right are the total expected losses under the three climate scenarios – Current Climate, Moderate CC and High CC.

The width of each bar on the cost curve represents the losses that would be avoided if the measure was put into place. Land drainage, for example, would avoid the most losses of all the measures. The bars are colored according to the type of risk the measure helps avoid (e.g., orange for inland flooding).

The y axis is the cost-benefit ratio for each measure, meaning how much the measure costs to implement relative to the benefits (the avoided costs from climate change) it produces. Measures with a C/B ratio of less than 1 produce more benefit than they cost. The bars are sorted in order of increasing cost to benefit, meaning that the ones on the left produce the most benefit for their cost while the ones to the right produce the least benefit for the most cost.

This curve notes the Expected Loss Averted by 2030 at USD 60-70 M, the sum of the costs avoided (the width of the bar) of all measures with a C/B Ratio less than 1.5, the proposed cut-off point for implementing a measure. The average of C/B ratios of the implemented measures is show to be 65 – 75%.

SLIDE 157



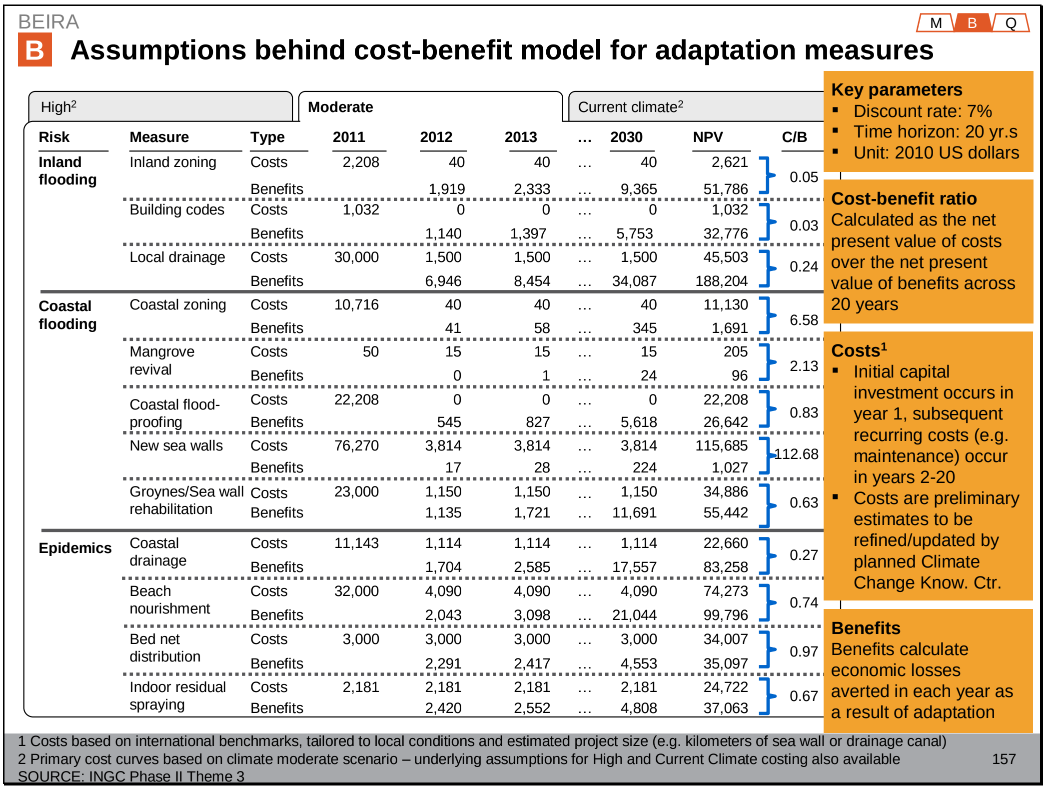
BEIRA

B Prevention and mitigation measures allow Beira to reduce the expected impact of disasters by ca. 43%

USD millions; Moderate climate change scenario

SOURCE: INGC Phase II Theme 3

SLIDE 158



BEIRA

B Assumptions behind cost-benefit model for adaptation measures

Risk	Measure	Type	2011	2012	2013	…	2030	NPV	C/B
Inland flooding	Inland zoning	Costs	2,208	40	40	…	40	2,621	0.05
		Benefits		1,919	2,333	…	9,365	51,786	
	Building codes	Costs	1,032	0	0	…	0	1,032	0.03
		Benefits		1,140	1,397	…	5,753	32,776	
	Local drainage	Costs	30,000	1,500	1,500	…	1,500	45,503	0.24
		Benefits		6,946	8,454	…	34,087	188,204	
Coastal flooding	Coastal zoning	Costs	10,716	40	40	…	40	11,130	6.58
		Benefits		41	58	…	345	1,691	
	Mangrove revival	Costs	50	15	15	…	15	205	2.13
		Benefits		0	1	…	24	96	
	Coastal flood-proofing	Costs	22,208	0	0	…	0	22,208	0.83
		Benefits		545	827	…	5,618	26,642	
	New sea walls	Costs	76,270	3,814	3,814	…	3,814	115,685	112.68
		Benefits		17	28	…	224	1,027	
	Groynes/Sea wall rehabilitation	Costs	23,000	1,150	1,150	…	1,150	34,886	0.63
		Benefits		1,135	1,721	…	11,691	55,442	
Epidemics	Coastal drainage	Costs	11,143	1,114	1,114	…	1,114	22,660	0.27
		Benefits		1,704	2,585	…	17,557	83,258	
	Beach nourishment	Costs	32,000	4,090	4,090	…	4,090	74,273	0.74
		Benefits		2,043	3,098	…	21,044	99,796	
	Bed net distribution	Costs	3,000	3,000	3,000	…	3,000	34,007	0.97
		Benefits		2,291	2,417	…	4,553	35,097	
	Indoor residual spraying	Costs	2,181	2,181	2,181	…	2,181	24,722	0.67
		Benefits		2,420	2,552	…	4,808	37,063	

Key parameters
- Discount rate: 7%
- Time horizon: 20 yr.s
- Unit: 2010 US dollars

Cost-benefit ratio
Calculated as the net present value of costs over the net present value of benefits across 20 years

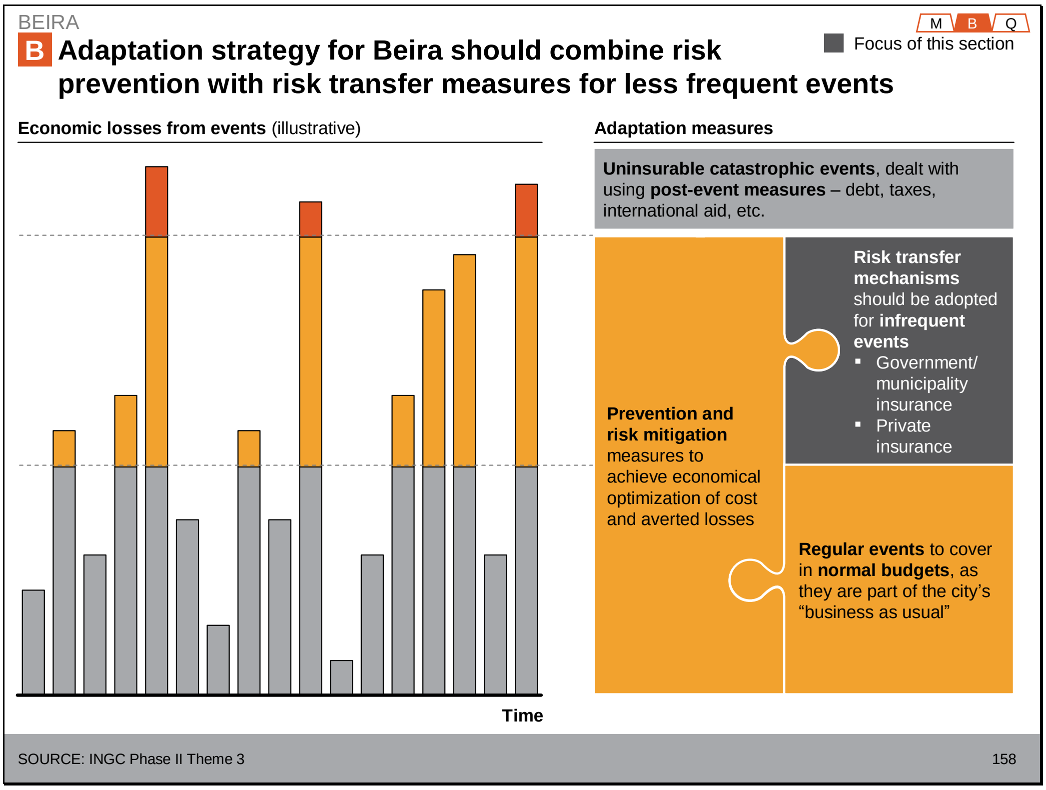
Costs[1]
- Initial capital investment occurs in year 1, subsequent recurring costs (e.g. maintenance) occur in years 2-20
- Costs are preliminary estimates to be refined/updated by planned Climate Change Know. Ctr.

Benefits
Benefits calculate economic losses averted in each year as a result of adaptation

[1] Costs based on international benchmarks, tailored to local conditions and estimated project size (e.g. kilometers of sea wall or drainage canal)
[2] Primary cost curves based on climate moderate scenario – underlying assumptions for High and Current Climate costing also available

SOURCE: INGC Phase II Theme 3

SLIDE 159



BEIRA

B Adaptation strategy for Beira should combine risk prevention with risk transfer measures for less frequent events

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

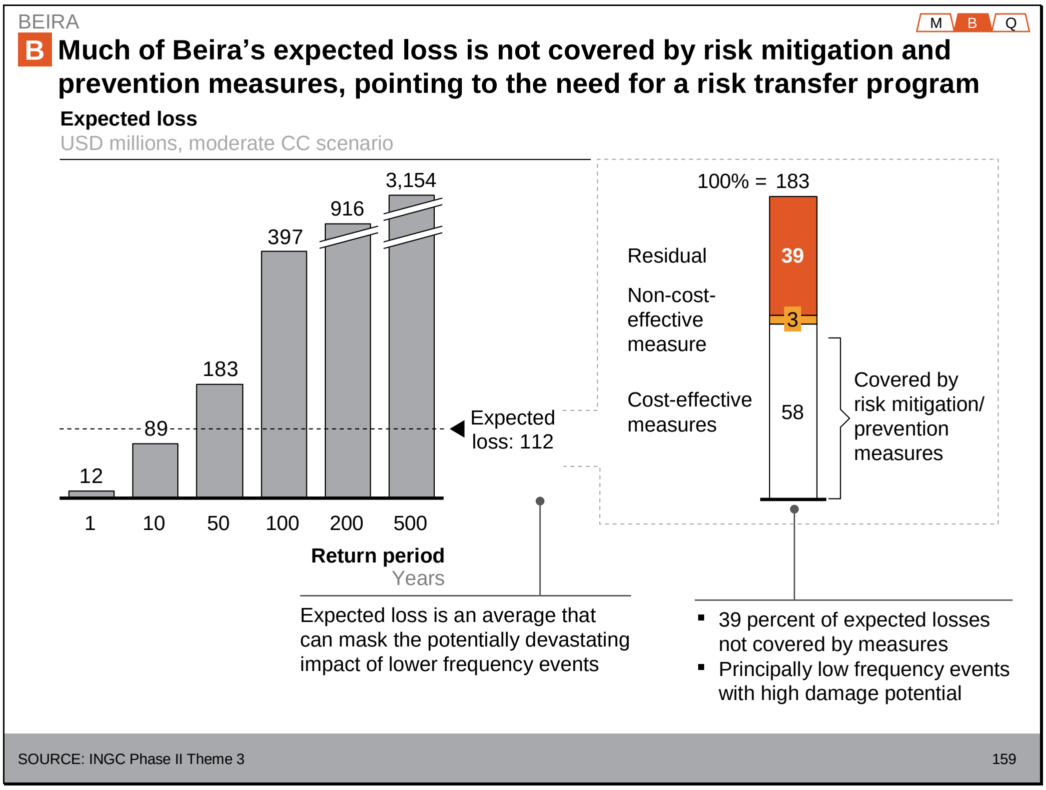
Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

Risk transfer mechanisms should be adopted for **infrequent events**
- Government/ municipality insurance
- Private insurance

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

SLIDE 160



BEIRA

B Much of Beira's expected loss is not covered by risk mitigation and prevention measures, pointing to the need for a risk transfer program

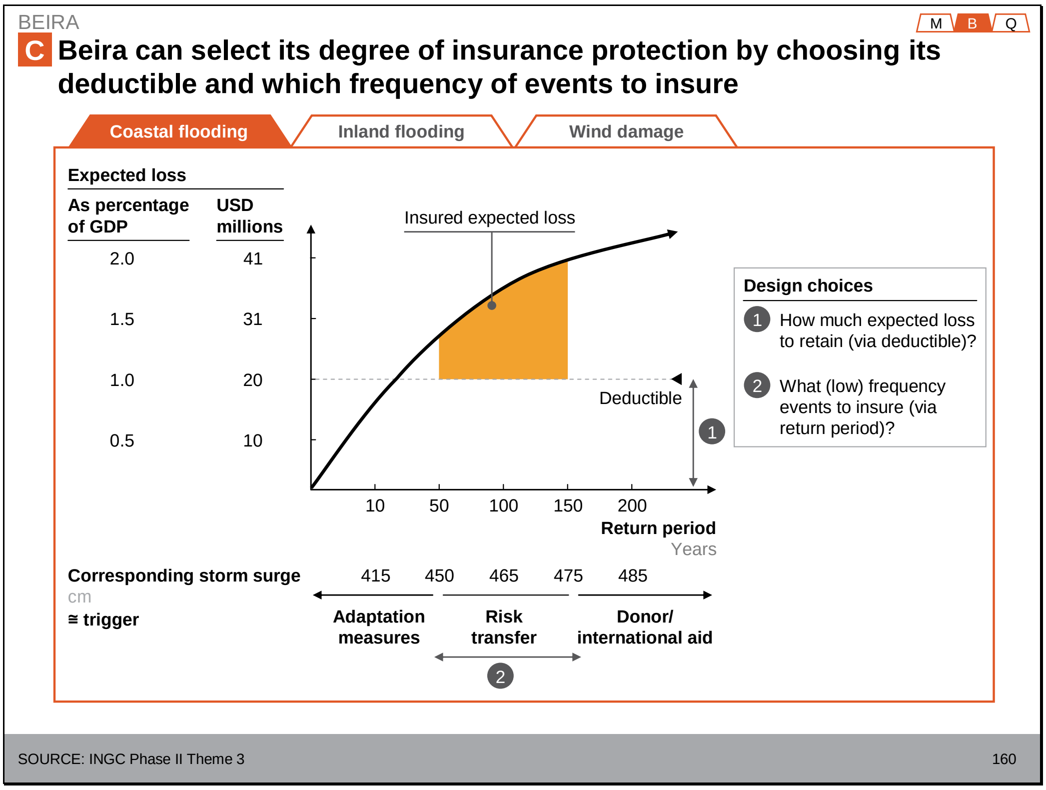
Expected loss
USD millions, moderate CC scenario

Expected loss is an average that can mask the potentially devastating impact of lower frequency events

- 39 percent of expected losses not covered by measures
- Principally low frequency events with high damage potential

SOURCE: INGC Phase II Theme 3

SLIDE 161



BEIRA

M B Q

C Beira can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

Coastal flooding | Inland flooding | Wind damage

Expected loss

As percentage of GDP	**USD millions**
2.0	41
1.5	31
1.0	20
0.5	10

Corresponding storm surge cm ≅ **trigger**	415	450	465	475	485

Design choices

1. How much expected loss to retain (via deductible)?
2. What (low) frequency events to insure (via return period)?

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 161:

Possible Adaptation Responses – Insurance Program Proposal module

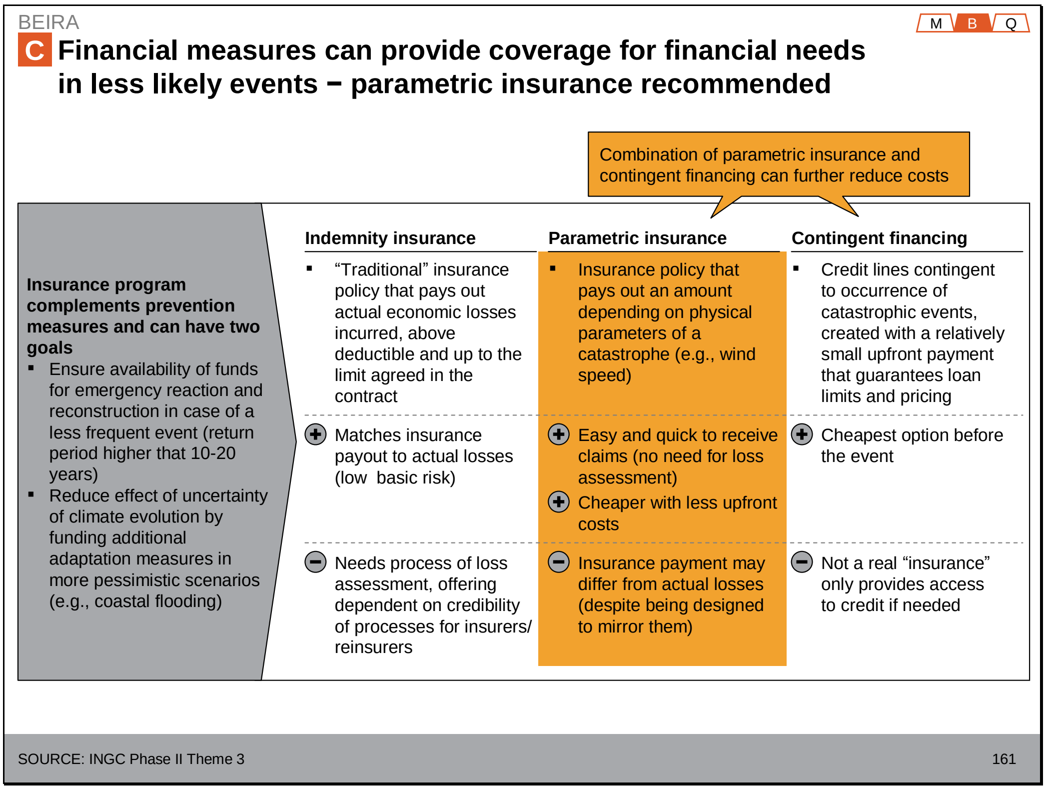
Beira can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

This chart plots the return period of a catastrophe (how often it occurs) against the expected loss from the event.

Beira can avoid the damages of events occurring with a relatively high frequency cost-effectively through adaptation measures. On the other end of the spectrum, there are events that occur only every several hundred years for which the municipality will need to rely on donor and international support.

In the middle of the spectrum are low probability, high impact events for which the municipality may want to transfer risk using a financial mechanism, e.g., an insurance policy. The municipality will need to determine how much risk to maintain on itself for these events, e.g., how high to set its deductible. As well, it must determine the range of events to cover with a risk transfer, e.g., events occurring ever 50 - 100 years, versus those occurring every 100 – 150 years.

SLIDE 162



BEIRA

C Financial measures can provide coverage for financial needs in less likely events – parametric insurance recommended

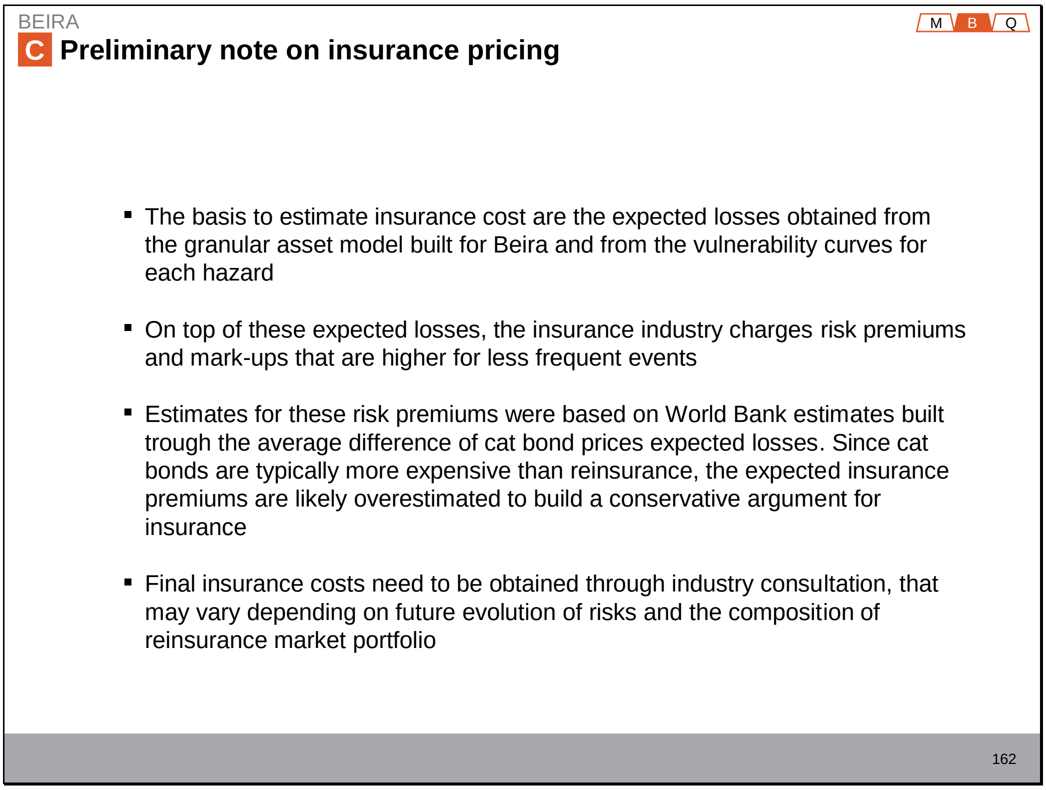
Combination of parametric insurance and contingent financing can further reduce costs

Insurance program complements prevention measures and can have two goals
- Ensure availability of funds for emergency reaction and reconstruction in case of a less frequent event (return period higher that 10-20 years)
- Reduce effect of uncertainty of climate evolution by funding additional adaptation measures in more pessimistic scenarios (e.g., coastal flooding)

Indemnity insurance	**Parametric insurance**	**Contingent financing**
▪ "Traditional" insurance policy that pays out actual economic losses incurred, above deductible and up to the limit agreed in the contract	▪ Insurance policy that pays out an amount depending on physical parameters of a catastrophe (e.g., wind speed)	▪ Credit lines contingent to occurrence of catastrophic events, created with a relatively small upfront payment that guarantees loan limits and pricing
⊕ Matches insurance payout to actual losses (low basic risk)	⊕ Easy and quick to receive claims (no need for loss assessment) ⊕ Cheaper with less upfront costs	⊕ Cheapest option before the event
⊖ Needs process of loss assessment, offering dependent on credibility of processes for insurers/ reinsurers	⊖ Insurance payment may differ from actual losses (despite being designed to mirror them)	⊖ Not a real "insurance" only provides access to credit if needed

SOURCE: INGC Phase II Theme 3

SLIDE 163

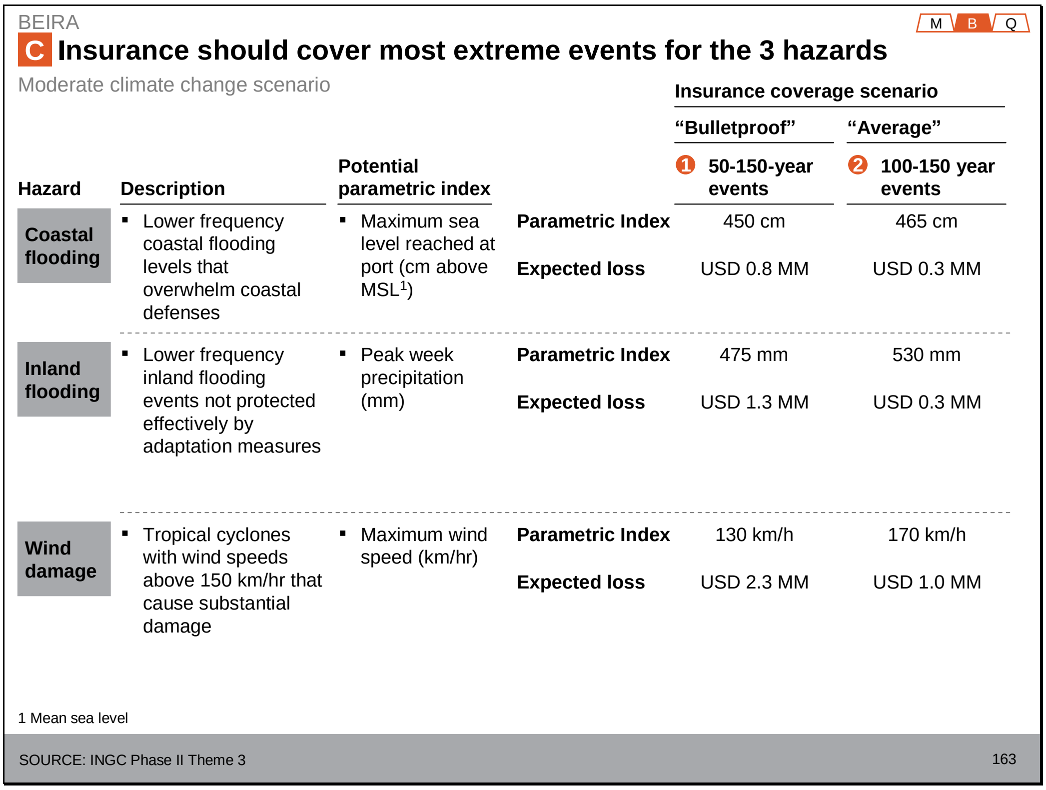


BEIRA

C Preliminary note on insurance pricing

- The basis to estimate insurance cost are the expected losses obtained from the granular asset model built for Beira and from the vulnerability curves for each hazard
- On top of these expected losses, the insurance industry charges risk premiums and mark-ups that are higher for less frequent events
- Estimates for these risk premiums were based on World Bank estimates built trough the average difference of cat bond prices expected losses. Since cat bonds are typically more expensive than reinsurance, the expected insurance premiums are likely overestimated to build a conservative argument for insurance
- Final insurance costs need to be obtained through industry consultation, that may vary depending on future evolution of risks and the composition of reinsurance market portfolio

SLIDE 164



BEIRA

M B Q

C Insurance should cover most extreme events for the 3 hazards

Moderate climate change scenario

				Insurance coverage scenario	
				“Bulletproof”	“Average”
Hazard	**Description**	**Potential parametric index**		❶ **50-150-year events**	❷ **100-150 year events**
Coastal flooding	▪ Lower frequency coastal flooding levels that overwhelm coastal defenses	▪ Maximum sea level reached at port (cm above MSL^1)	**Parametric Index**	450 cm	465 cm
			Expected loss	USD 0.8 MM	USD 0.3 MM
Inland flooding	▪ Lower frequency inland flooding events not protected effectively by adaptation measures	▪ Peak week precipitation (mm)	**Parametric Index**	475 mm	530 mm
			Expected loss	USD 1.3 MM	USD 0.3 MM
Wind damage	▪ Tropical cyclones with wind speeds above 150 km/hr that cause substantial damage	▪ Maximum wind speed (km/hr)	**Parametric Index**	130 km/h	170 km/h
			Expected loss	USD 2.3 MM	USD 1.0 MM

1 Mean sea level

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 164:

Possible Adaptation Responses – Insurance Program Proposal module

Insurance should cover most extreme events for the 3 hazards

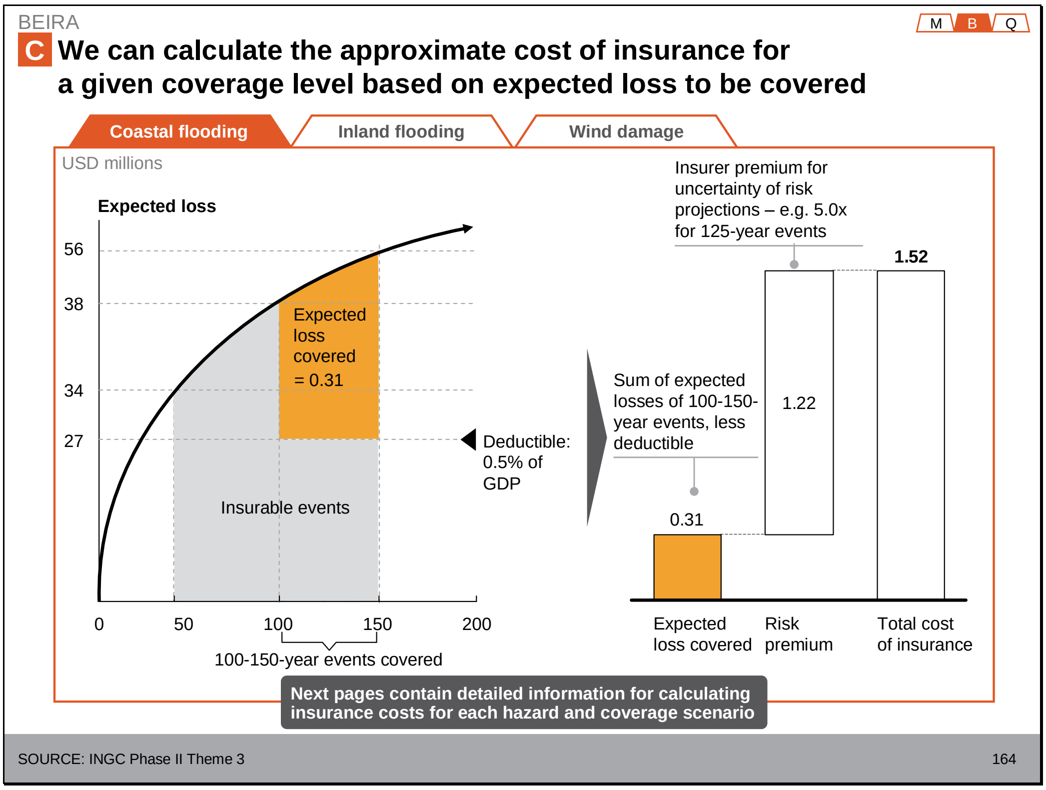
Beira could purchase insurance to protect itself against catastrophic losses associated with three major climate events.

Two levels of insurance are described, a “bulletproof” policy level that would cover the municipality against severe events projected to occur only every 50-150 years, and an “average” policy level that would only cover the events projected to occur once every 100-150 years.

For each level of insurance and each event type, a “parametric index” is listed, meaning an event that would trigger an automatic payout of the insurance coverage. For example, for the “bulletproof” policy for coastal flooding, the insurance would pay out automatically when sea level at port reaches 450cm above MSL.

Expected losses are also listed for each policy level – the losses are greater for the bulletproof policies because, while the triggering events are on average less severe for the 50-150 year events, they also are projected to occur more often.

SLIDE 165



BEIRA

M B Q

C We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

Next pages contain detailed information for calculating insurance costs for each hazard and coverage scenario

SOURCE: INGC Phase II Theme 3

164

NOTES FOR SLIDE 165:

Possible Adaptation Responses – Insurance Program Proposal module

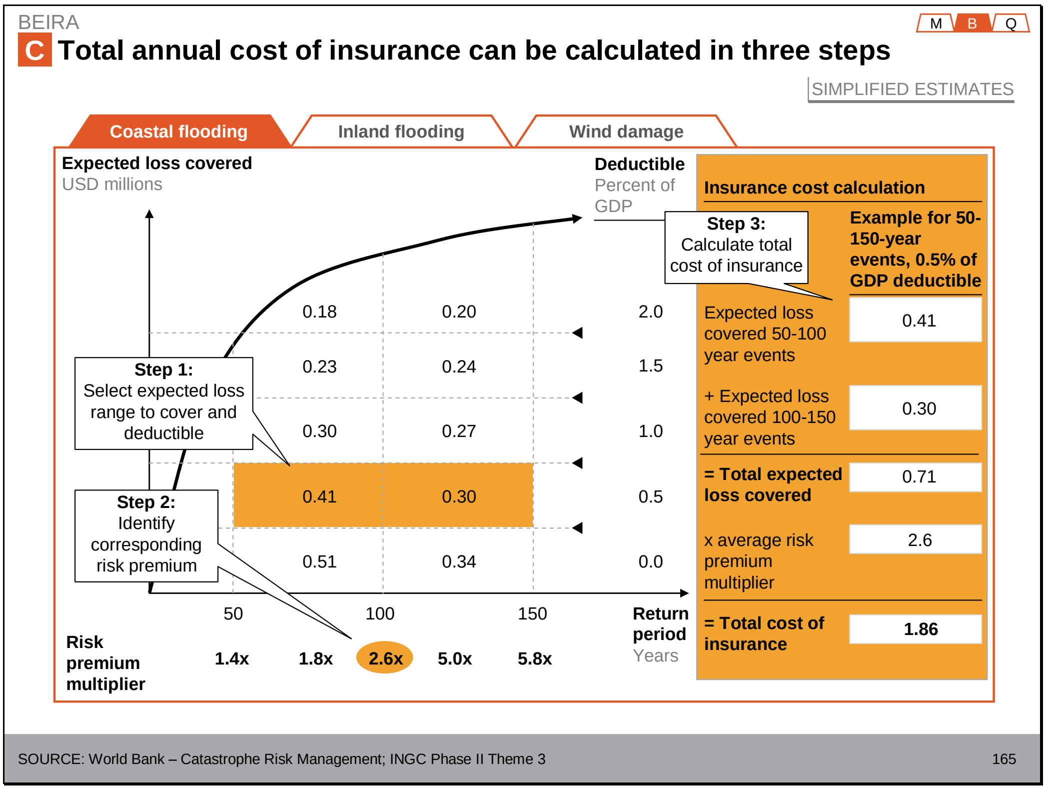
We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

First, the municipality needs to determine the range of expected loss to cover, which is a function of the range of insurable events covered by the policy, and the deductible under which the municipality will cover costs itself.

In this example, the range of events covered for coastal flooding is shown to be 100-150 year events, and the municipality has agreed to a deductible of 0.5% of it's GDP, meaning that the insurance policy will only cover losses above that level. This means that the insurer will be covering the amount between the deductible and the total expected loss for that range of events, which translates to a USD 0.31 M annual insurance premium for the coverage.

Given that expected loss coverage, an estimate for the total cost of the insurance is possible. Because of the uncertainty of predictions required for these events, insurers will charge a "risk premium" that is some multiple of the expected loss covered. In this case, the risk premium multiplier for ~125 year events is ~5.0x, for a risk premium of 1.22 M. This is added to the expected loss covered to produced a total cost of insurance of 1.52 M.

SLIDE 166



BEIRA

C Total annual cost of insurance can be calculated in three steps

SIMPLIFIED ESTIMATES

0.18	0.20	2.0
0.23	0.24	1.5
0.30	0.27	1.0
0.41	0.30	0.5
0.51	0.34	0.0

Step 1: Select expected loss range to cover and deductible

Step 2: Identify corresponding risk premium

Step 3: Calculate total cost of insurance

Insurance cost calculation

	Example for 50-150-year events, 0.5% of GDP deductible
Expected loss covered 50-100 year events	0.41
+ Expected loss covered 100-150 year events	0.30
= Total expected loss covered	0.71
x average risk premium multiplier	2.6
= Total cost of insurance	**1.86**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

NOTES FOR SLIDE 166:

Possible Adaptation Responses – Insurance Program Proposal module

Total annual cost of insurance can be calculated in three steps

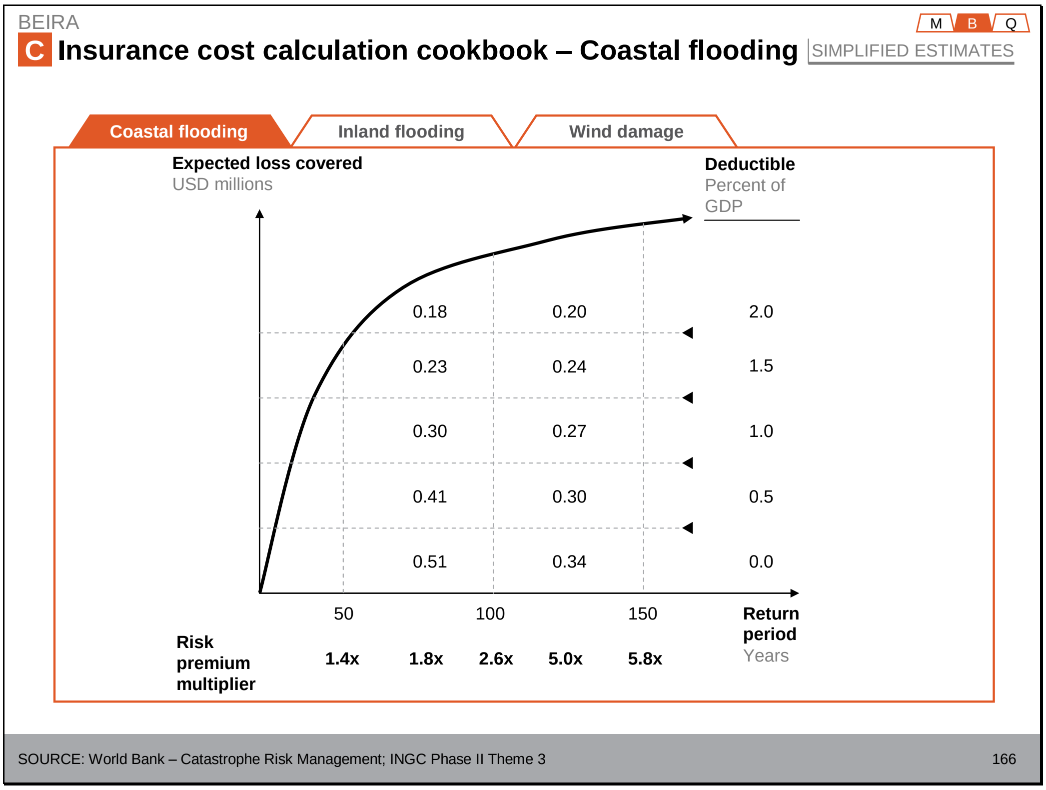
This page displays a more detailed explanation of the total cost of insurance concept from the previous page.

The first step shown is to select a range of events to cover, and a deductible under which the municipality will cover itself.

The second step is to identify the risk premium multiplier that corresponds with that coverage range.

The third step is to calculate the total cost of insurance by multiplying the total expected loss covered by the risk premium multiplier to get the risk premium. The total expected loss covered and the risk premium are then added together to generate the total cost of insurance.

SLIDE 167



BEIRA

C Insurance cost calculation cookbook – Coastal flooding SIMPLIFIED ESTIMATES

0.18	0.20	2.0
0.23	0.24	1.5
0.30	0.27	1.0
0.41	0.30	0.5
0.51	0.34	0.0

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

166

NOTES FOR SLIDE 167:

Possible Adaptation Responses – Insurance Program Proposal module

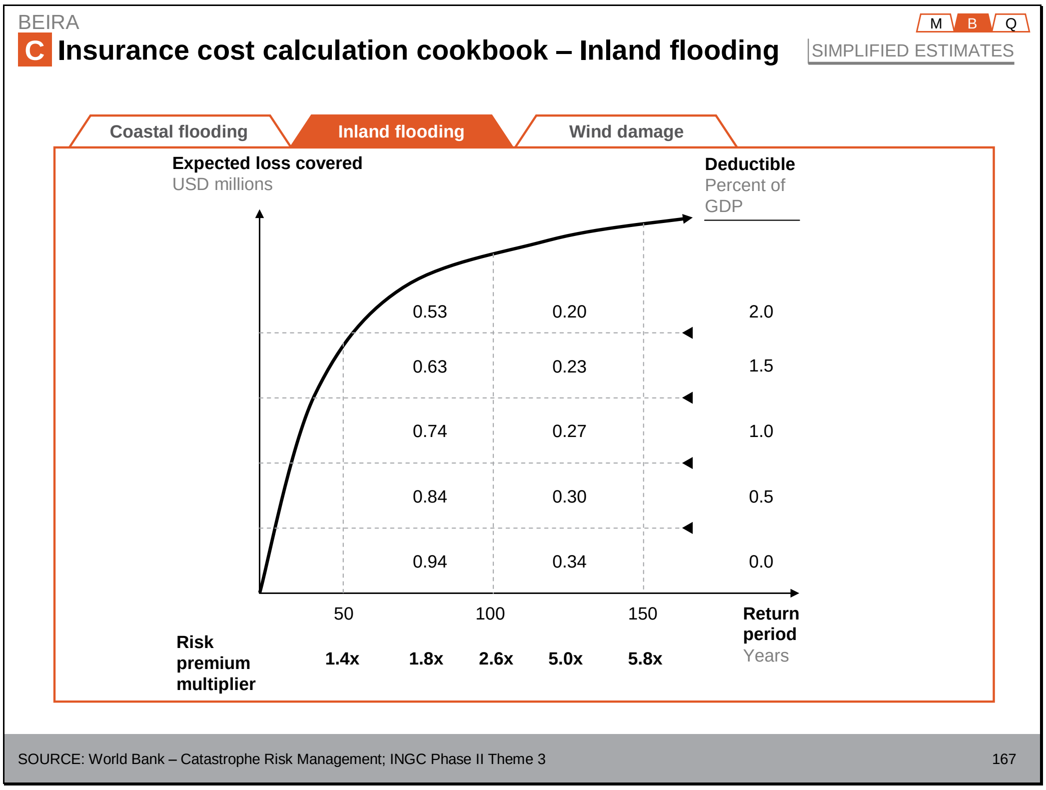
Insurance cost calculation cookbook – Coastal flooding

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Beira in considering it's likely insurance cost for coastal flooding.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 168



BEIRA

M B Q

C Insurance cost calculation cookbook – Inland flooding

SIMPLIFIED ESTIMATES

Coastal flooding | **Inland flooding** | Wind damage

Expected loss covered
USD millions

Deductible
Percent of GDP

0.53	0.20	2.0
0.63	0.23	1.5
0.74	0.27	1.0
0.84	0.30	0.5
0.94	0.34	0.0

Return period
Years

Risk premium multiplier	**1.4x**	**1.8x**	**2.6x**	**5.0x**	**5.8x**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

167

NOTES FOR SLIDE 168:

Possible Adaptation Responses – Insurance Program Proposal module

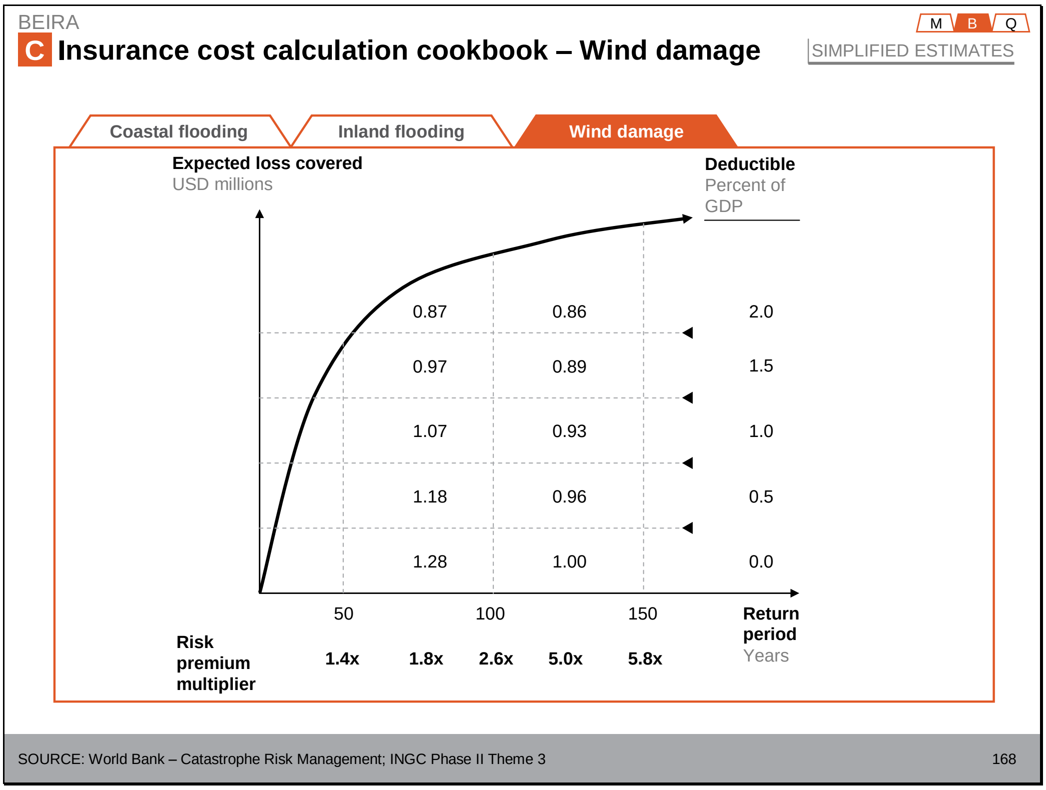
Insurance cost calculation cookbook – Inland flooding

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Beira in considering it’s likely insurance cost for inland flooding.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 169



BEIRA

C Insurance cost calculation cookbook – Wind damage

M B Q

SIMPLIFIED ESTIMATES

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

168

NOTES FOR SLIDE 169:

Possible Adaptation Responses – Insurance Program Proposal module

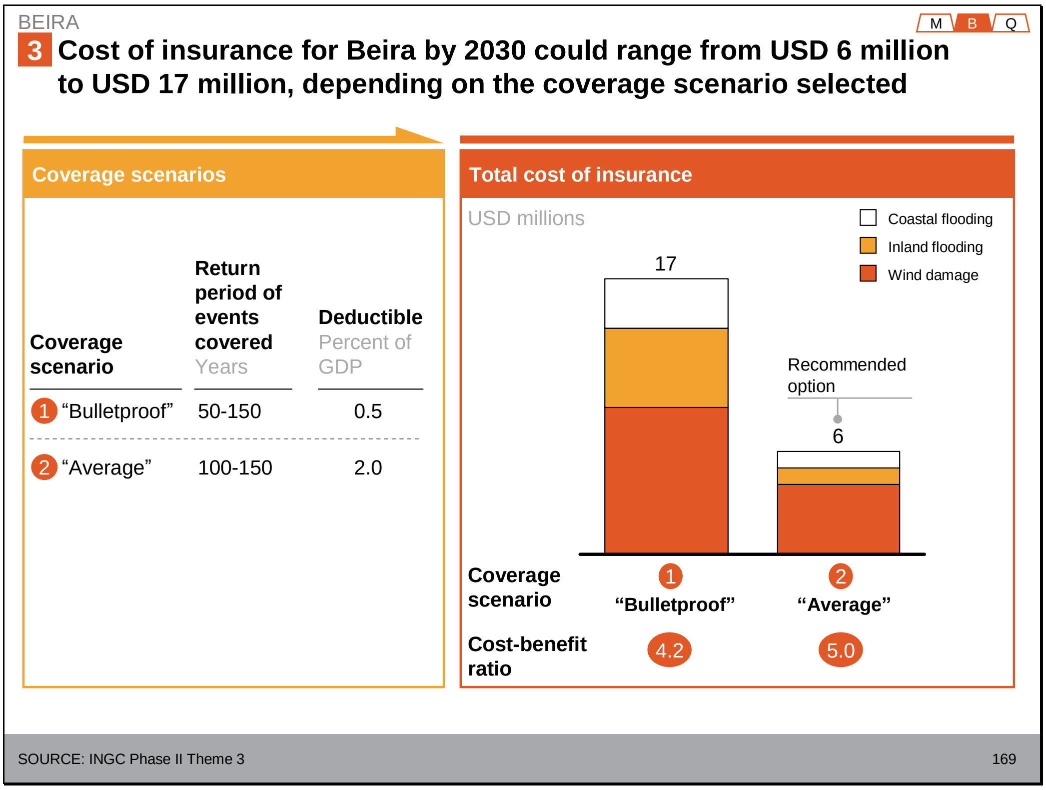
Insurance cost calculation cookbook – Wind damage

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Beira in considering it's likely insurance cost for Wind damage.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 170



BEIRA

M B Q

3 Cost of insurance for Beira by 2030 could range from USD 6 million to USD 17 million, depending on the coverage scenario selected

Coverage scenarios

Coverage scenario	Return period of events covered Years	Deductible Percent of GDP
① "Bulletproof"	50-150	0.5
② "Average"	100-150	2.0

Total cost of insurance

Coverage scenario	① "Bulletproof"	② "Average"
Cost-benefit ratio	4.2	5.0

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 170:

Possible Adaptation Responses – Insurance Program Proposal module

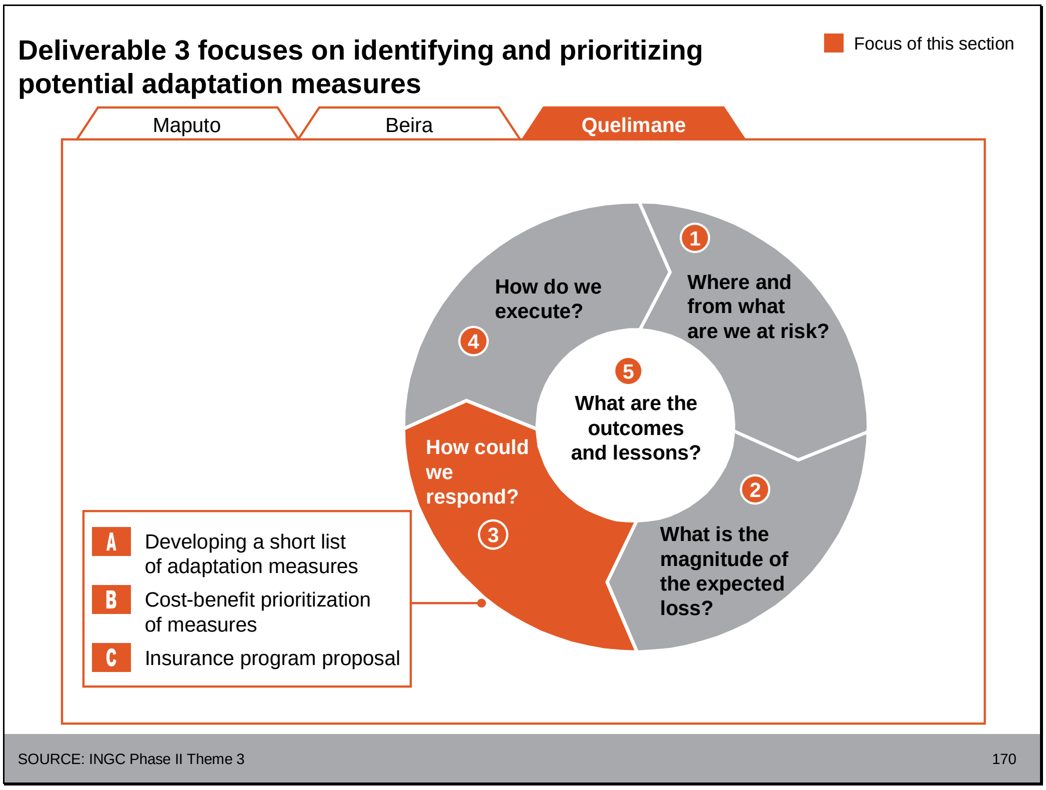
Cost of insurance for Beira by 2030 could range from USD 6 million to USD 17 million, depending on the coverage scenario selected

Two different coverage scenarios are described here. The first (the "bulletproof") has a wider range of events covered (50-150 year events), and a lower deductible – 0.5% of GDP. The second (the "average") chooses a narrower range of events to cover (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks for each hazard type on the previous pages to calculate the total cost of insurance, the annual costs were identified and added in the bars on the right for each scenario.

Lastly, the Cost-benefit ratios were calculated for each insurance policy, showing the amount paid for the policy divided by the estimated payouts. Because of the large risk premiums for these policies, the cost benefit ratios for both coverage scenarios are quite poor (meaning much greater than 1), particularly when compared with other direct prevention measures.

SLIDE 171



Deliverable 3 focuses on identifying and prioritizing potential adaptation measures

🟥 Focus of this section

Maputo | Beira | **Quelimane**

① Where and from what are we at risk?

② What is the magnitude of the expected loss?

③ How could we respond?

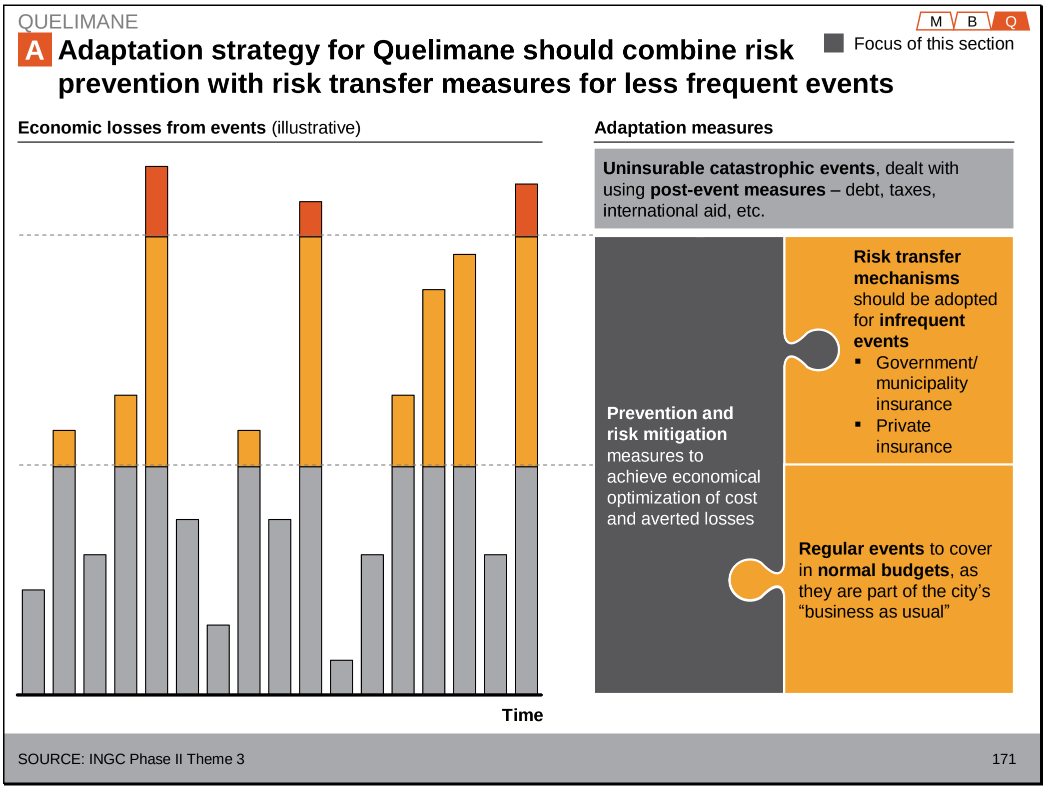
④ How do we execute?

⑤ What are the outcomes and lessons?

- **A** Developing a short list of adaptation measures
- **B** Cost-benefit prioritization of measures
- **C** Insurance program proposal

SOURCE: INGC Phase II Theme 3

SLIDE 172



QUELIMANE

M | B | Q

A Adaptation strategy for Quelimane should combine risk prevention with risk transfer measures for less frequent events

⬛ Focus of this section

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

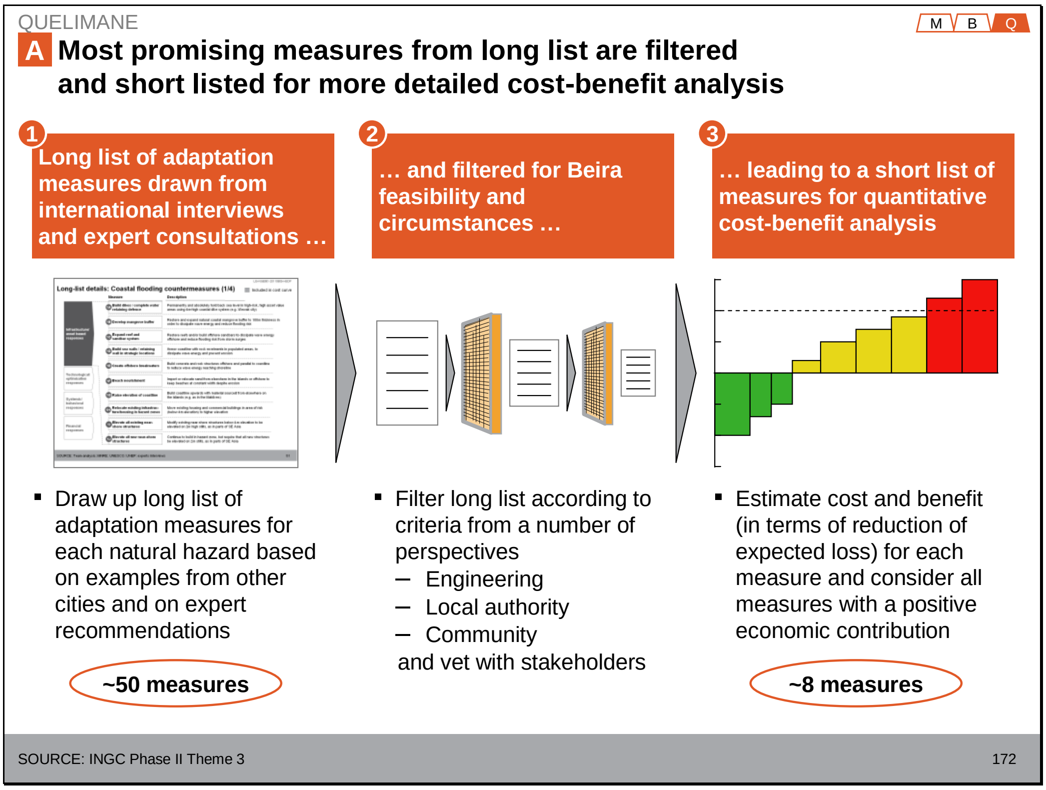
Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

Risk transfer mechanisms should be adopted for **infrequent events**
- Government/ municipality insurance
- Private insurance

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

SLIDE 173



QUELIMANE

M B Q

A Most promising measures from long list are filtered and short listed for more detailed cost-benefit analysis

1 Long list of adaptation measures drawn from international interviews and expert consultations …

- Draw up long list of adaptation measures for each natural hazard based on examples from other cities and on expert recommendations

~50 measures

2 … and filtered for Beira feasibility and circumstances …

- Filter long list according to criteria from a number of perspectives
  - Engineering
  - Local authority
  - Community

  and vet with stakeholders

3 … leading to a short list of measures for quantitative cost-benefit analysis

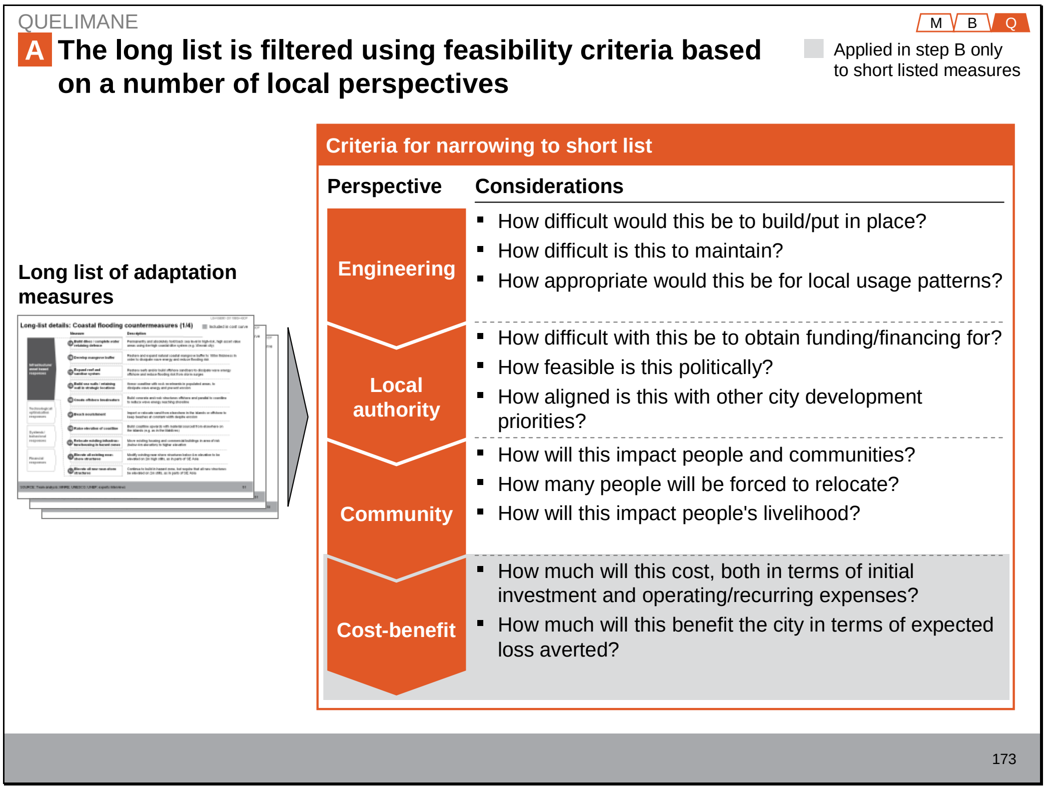
- Estimate cost and benefit (in terms of reduction of expected loss) for each measure and consider all measures with a positive economic contribution

~8 measures

SOURCE: INGC Phase II Theme 3

172

SLIDE 174



QUELIMANE

M B Q

A The long list is filtered using feasibility criteria based on a number of local perspectives

▢ Applied in step B only to short listed measures

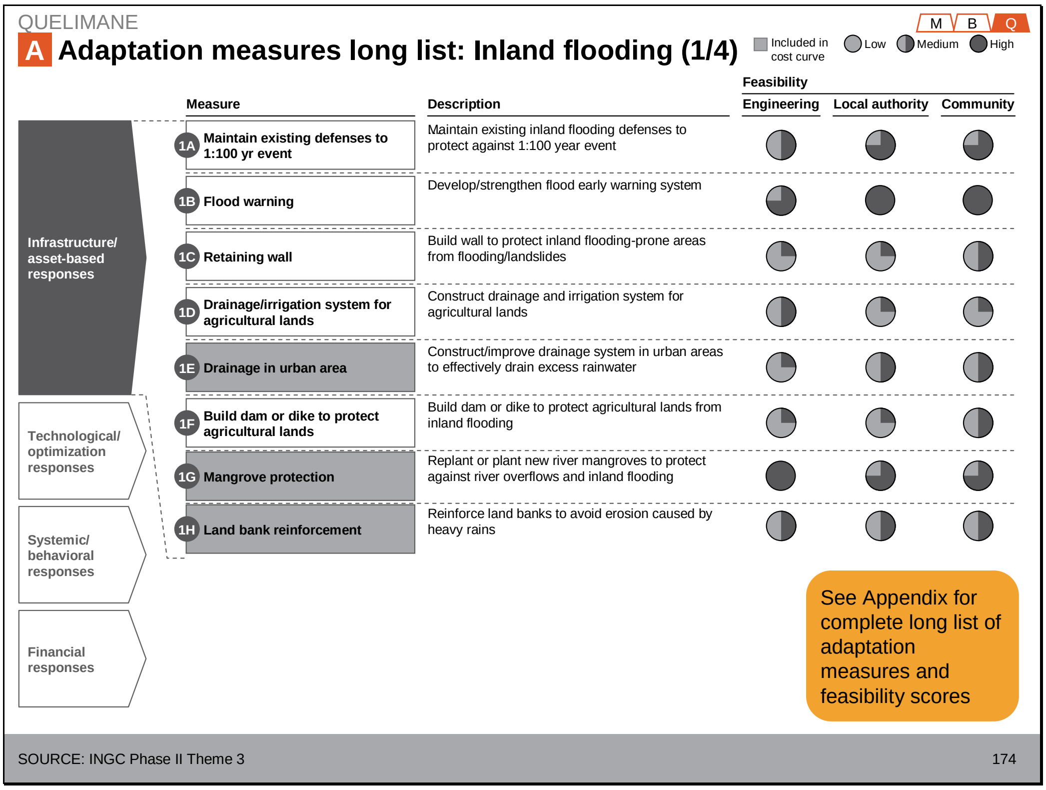
Long list of adaptation measures

Criteria for narrowing to short list

Perspective	Considerations
Engineering	How difficult would this be to build/put in place? How difficult is this to maintain? How appropriate would this be for local usage patterns?
Local authority	How difficult with this be to obtain funding/financing for? How feasible is this politically? How aligned is this with other city development priorities?
Community	How will this impact people and communities? How many people will be forced to relocate? How will this impact people's livelihood?
Cost-benefit	How much will this cost, both in terms of initial investment and operating/recurring expenses? How much will this benefit the city in terms of expected loss averted?

173

SLIDE 175



QUELIMANE

A Adaptation measures long list: Inland flooding (1/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset-based responses
Technological/ optimization responses
Systemic/ behavioral responses
Financial responses

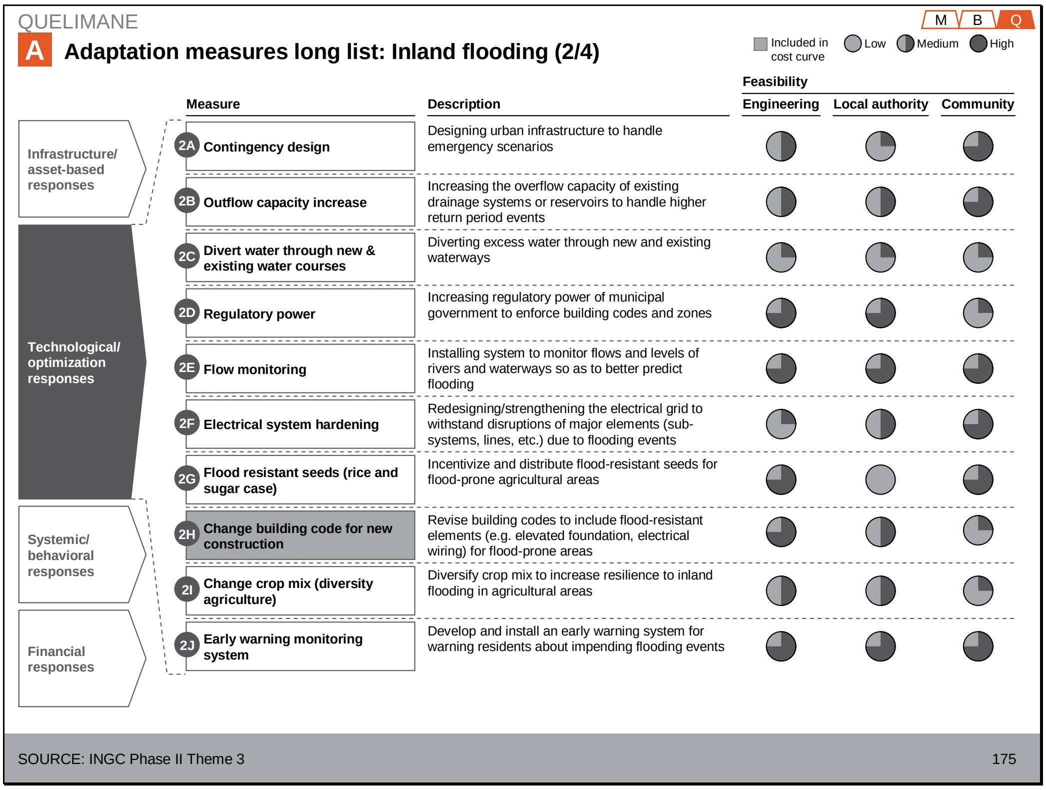
Measure	Description	Feasibility Engineering	Local authority	Community
1A Maintain existing defenses to 1:100 yr event	Maintain existing inland flooding defenses to protect against 1:100 year event	◑	◕	◕
1B Flood warning	Develop/strengthen flood early warning system	◕	●	●
1C Retaining wall	Build wall to protect inland flooding-prone areas from flooding/landslides	◔	◔	◑
1D Drainage/irrigation system for agricultural lands	Construct drainage and irrigation system for agricultural lands	◑	◔	◔
▨ **1E Drainage in urban area**	Construct/improve drainage system in urban areas to effectively drain excess rainwater	◔	◑	◑
1F Build dam or dike to protect agricultural lands	Build dam or dike to protect agricultural lands from inland flooding	◔	◔	◑
▨ **1G Mangrove protection**	Replant or plant new river mangroves to protect against river overflows and inland flooding	●	◕	◕
▨ **1H Land bank reinforcement**	Reinforce land banks to avoid erosion caused by heavy rains	◑	◑	◑

See Appendix for complete long list of adaptation measures and feasibility scores

SOURCE: INGC Phase II Theme 3

174

SLIDE 176



QUELIMANE

A Adaptation measures long list: Inland flooding (2/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

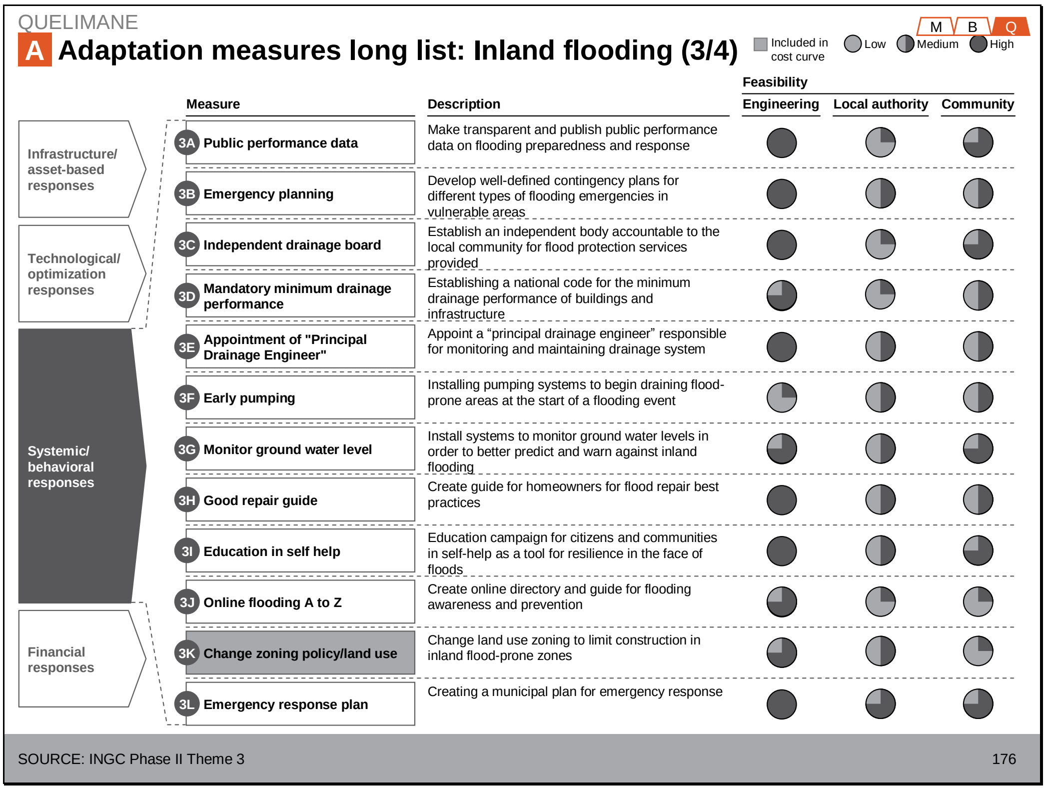
Infrastructure/ asset-based responses
Technological/ optimization responses
Systemic/ behavioral responses
Financial responses

Measure	Description	Feasibility Engineering	Local authority	Community
2A Contingency design	Designing urban infrastructure to handle emergency scenarios	◑	◔	◕
2B Outflow capacity increase	Increasing the overflow capacity of existing drainage systems or reservoirs to handle higher return period events	◑	◑	◕
2C Divert water through new & existing water courses	Diverting excess water through new and existing waterways	◔	◔	◔
2D Regulatory power	Increasing regulatory power of municipal government to enforce building codes and zones	◕	◕	◔
2E Flow monitoring	Installing system to monitor flows and levels of rivers and waterways so as to better predict flooding	◕	◕	◕
2F Electrical system hardening	Redesigning/strengthening the electrical grid to withstand disruptions of major elements (sub-systems, lines, etc.) due to flooding events	◔	◑	◕
2G Flood resistant seeds (rice and sugar case)	Incentivize and distribute flood-resistant seeds for flood-prone agricultural areas	◕	○	◕
▨ **2H Change building code for new construction**	Revise building codes to include flood-resistant elements (e.g. elevated foundation, electrical wiring) for flood-prone areas	◕	◑	◔
2I Change crop mix (diversity agriculture)	Diversify crop mix to increase resilience to inland flooding in agricultural areas	◑	◑	◔
2J Early warning monitoring system	Develop and install an early warning system for warning residents about impending flooding events	◕	◕	◕

SOURCE: INGC Phase II Theme 3

175

SLIDE 177



QUELIMANE

A Adaptation measures long list: Inland flooding (3/4)

M B Q

▨ Included in cost curve ○ Low ◐ Medium ● High

Infrastructure/ asset-based responses

Technological/ optimization responses

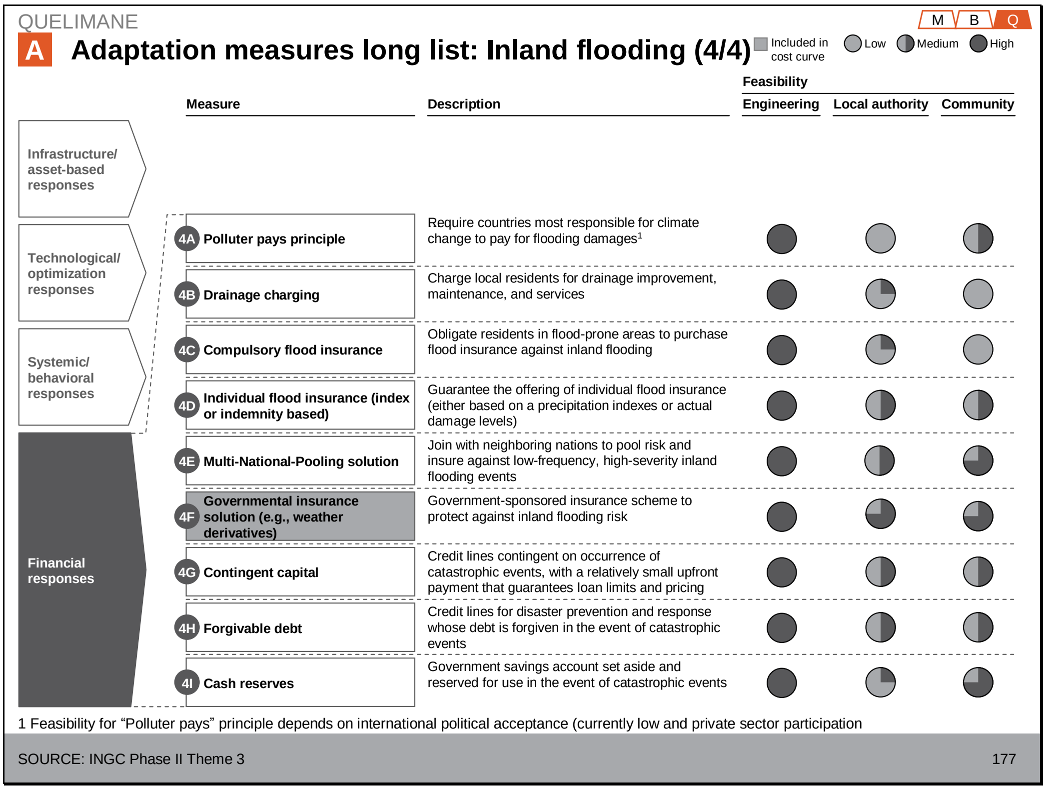
Systemic/ behavioral responses

Financial responses

Measure	Description	Feasibility Engineering	 Local authority	 Community
3A Public performance data	Make transparent and publish public performance data on flooding preparedness and response	●	◔	◕
3B Emergency planning	Develop well-defined contingency plans for different types of flooding emergencies in vulnerable areas	●	◐	◐
3C Independent drainage board	Establish an independent body accountable to the local community for flood protection services provided	●	◔	◕
3D Mandatory minimum drainage performance	Establishing a national code for the minimum drainage performance of buildings and infrastructure	◕	◔	◐
3E Appointment of "Principal Drainage Engineer"	Appoint a “principal drainage engineer” responsible for monitoring and maintaining drainage system	●	◐	◐
3F Early pumping	Installing pumping systems to begin draining flood-prone areas at the start of a flooding event	◔	◐	◐
3G Monitor ground water level	Install systems to monitor ground water levels in order to better predict and warn against inland flooding	◕	◐	◕
3H Good repair guide	Create guide for homeowners for flood repair best practices	●	◐	◐
3I Education in self help	Education campaign for citizens and communities in self-help as a tool for resilience in the face of floods	●	◐	◕
3J Online flooding A to Z	Create online directory and guide for flooding awareness and prevention	◕	◔	◔
3K Change zoning policy/land use	Change land use zoning to limit construction in inland flood-prone zones	◕	◐	◔
3L Emergency response plan	Creating a municipal plan for emergency response	●	◕	◕

SOURCE: INGC Phase II Theme 3

SLIDE 178



QUELIMANE

A Adaptation measures long list: Inland flooding (4/4)

M B Q

▨ Included in cost curve ○ Low ◐ Medium ● High

Infrastructure/ asset-based responses

Technological/ optimization responses

Systemic/ behavioral responses

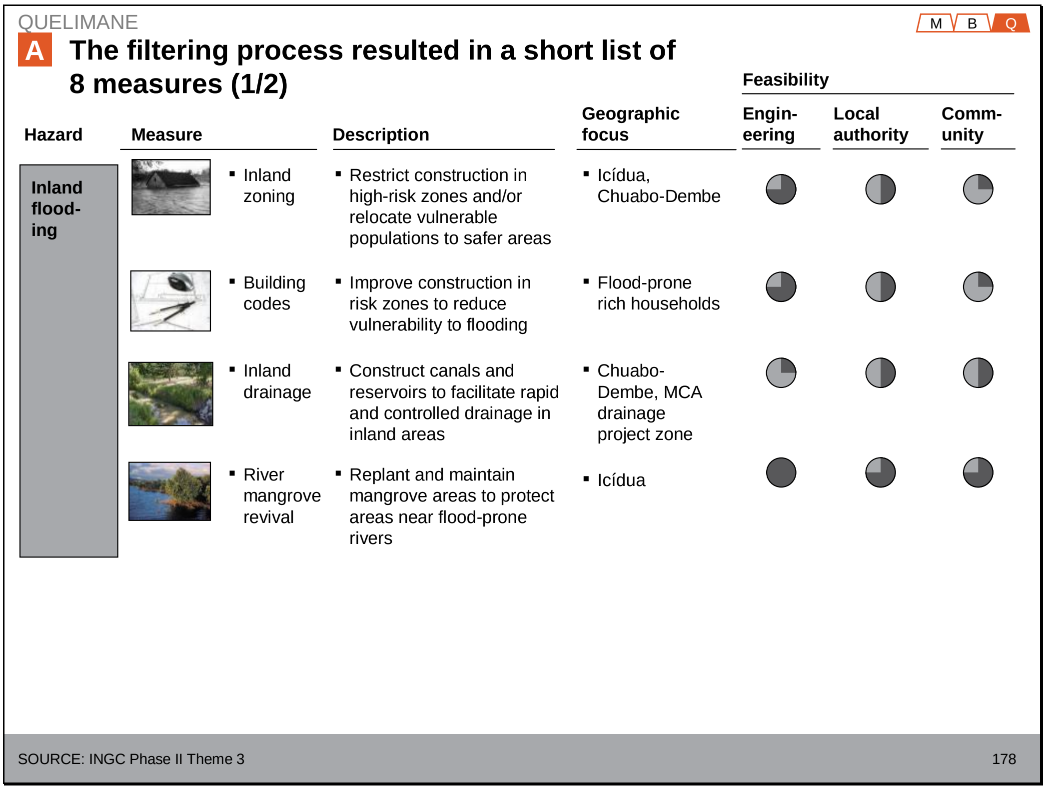
Financial responses

Measure	Description	Feasibility Engineering	 Local authority	 Community
4A Polluter pays principle	Require countries most responsible for climate change to pay for flooding damages[1]	●	○	◐
4B Drainage charging	Charge local residents for drainage improvement, maintenance, and services	●	◔	○
4C Compulsory flood insurance	Obligate residents in flood-prone areas to purchase flood insurance against inland flooding	●	◔	○
4D Individual flood insurance (index or indemnity based)	Guarantee the offering of individual flood insurance (either based on a precipitation indexes or actual damage levels)	●	◐	◐
4E Multi-National-Pooling solution	Join with neighboring nations to pool risk and insure against low-frequency, high-severity inland flooding events	●	◐	◕
4F Governmental insurance solution (e.g., weather derivatives)	Government-sponsored insurance scheme to protect against inland flooding risk	●	◕	◕
4G Contingent capital	Credit lines contingent on occurrence of catastrophic events, with a relatively small upfront payment that guarantees loan limits and pricing	●	◐	◐
4H Forgivable debt	Credit lines for disaster prevention and response whose debt is forgiven in the event of catastrophic events	●	◐	◐
4I Cash reserves	Government savings account set aside and reserved for use in the event of catastrophic events	●	◔	◕

[1] Feasibility for “Polluter pays” principle depends on international political acceptance (currently low and private sector participation

SOURCE: INGC Phase II Theme 3

SLIDE 179



QUELIMANE

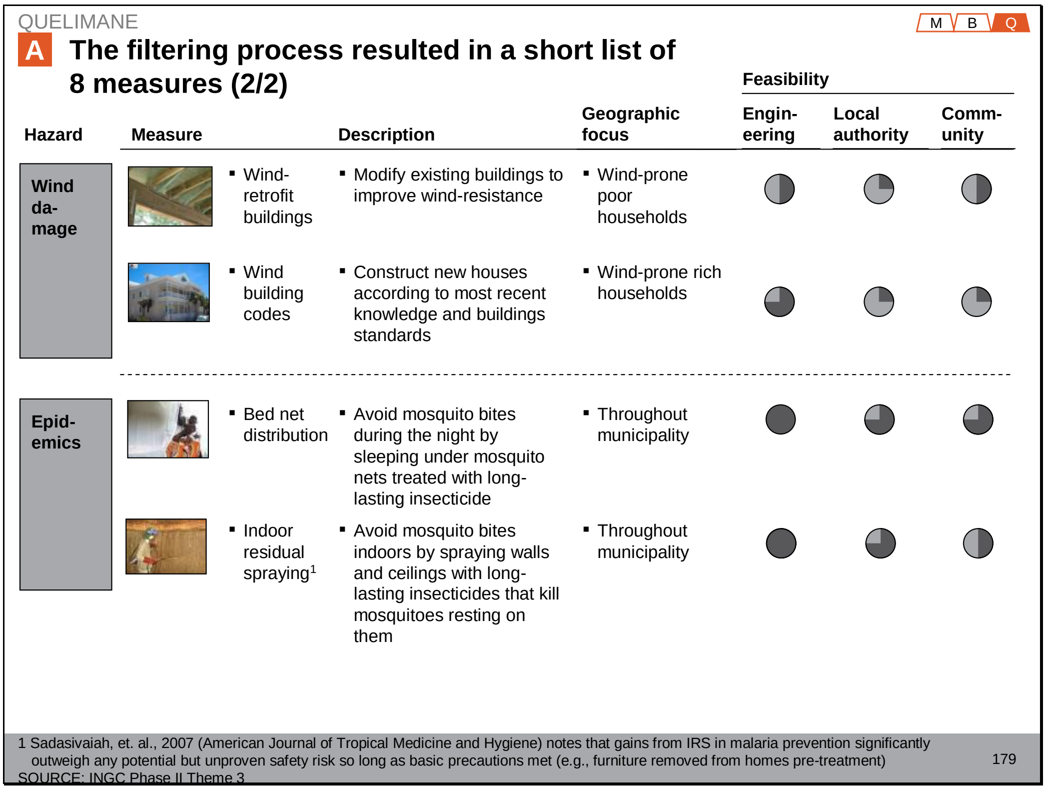
M B Q

A The filtering process resulted in a short list of 8 measures (1/2)

Hazard		Measure	Description	Geographic focus	Feasibility: Engin-eering	Feasibility: Local authority	Feasibility: Comm-unity
Inland flood-ing		Inland zoning	Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	Icídua, Chuabo-Dembe	◕	◑	◔
		Building codes	Improve construction in risk zones to reduce vulnerability to flooding	Flood-prone rich households	◕	◑	◔
		Inland drainage	Construct canals and reservoirs to facilitate rapid and controlled drainage in inland areas	Chuabo-Dembe, MCA drainage project zone	◔	◑	◑
		River mangrove revival	Replant and maintain mangrove areas to protect areas near flood-prone rivers	Icídua	●	◕	◕

SOURCE: INGC Phase II Theme 3

SLIDE 180



QUELIMANE

M B Q

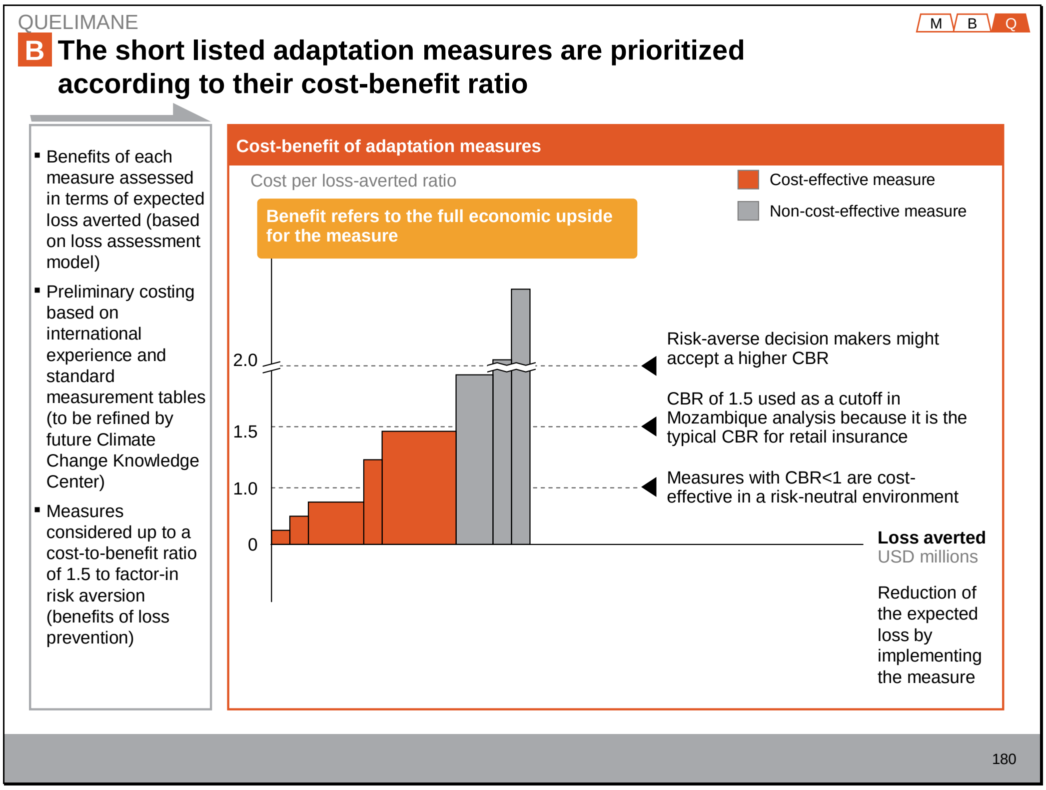
A The filtering process resulted in a short list of 8 measures (2/2)

Hazard		Measure	Description	Geographic focus	Feasibility: Engin-eering	Feasibility: Local authority	Feasibility: Comm-unity
Wind da-mage		Wind-retrofit buildings	Modify existing buildings to improve wind-resistance	Wind-prone poor households	◑	◔	◑
		Wind building codes	Construct new houses according to most recent knowledge and buildings standards	Wind-prone rich households	◕	◔	◔
Epid-emics		Bed net distribution	Avoid mosquito bites during the night by sleeping under mosquito nets treated with long-lasting insecticide	Throughout municipality	●	◕	◕
		Indoor residual spraying[1]	Avoid mosquito bites indoors by spraying walls and ceilings with long-lasting insecticides that kill mosquitoes resting on them	Throughout municipality	●	◕	◑

[1] Sadasivaiah, et. al., 2007 (American Journal of Tropical Medicine and Hygiene) notes that gains from IRS in malaria prevention significantly outweigh any potential but unproven safety risk so long as basic precautions met (e.g., furniture removed from homes pre-treatment)

SOURCE: INGC Phase II Theme 3

SLIDE 181



QUELIMANE

B The short listed adaptation measures are prioritized according to their cost-benefit ratio

- Benefits of each measure assessed in terms of expected loss averted (based on loss assessment model)
- Preliminary costing based on international experience and standard measurement tables (to be refined by future Climate Change Knowledge Center)
- Measures considered up to a cost-to-benefit ratio of 1.5 to factor-in risk aversion (benefits of loss prevention)

Cost-benefit of adaptation measures

Benefit refers to the full economic upside for the measure

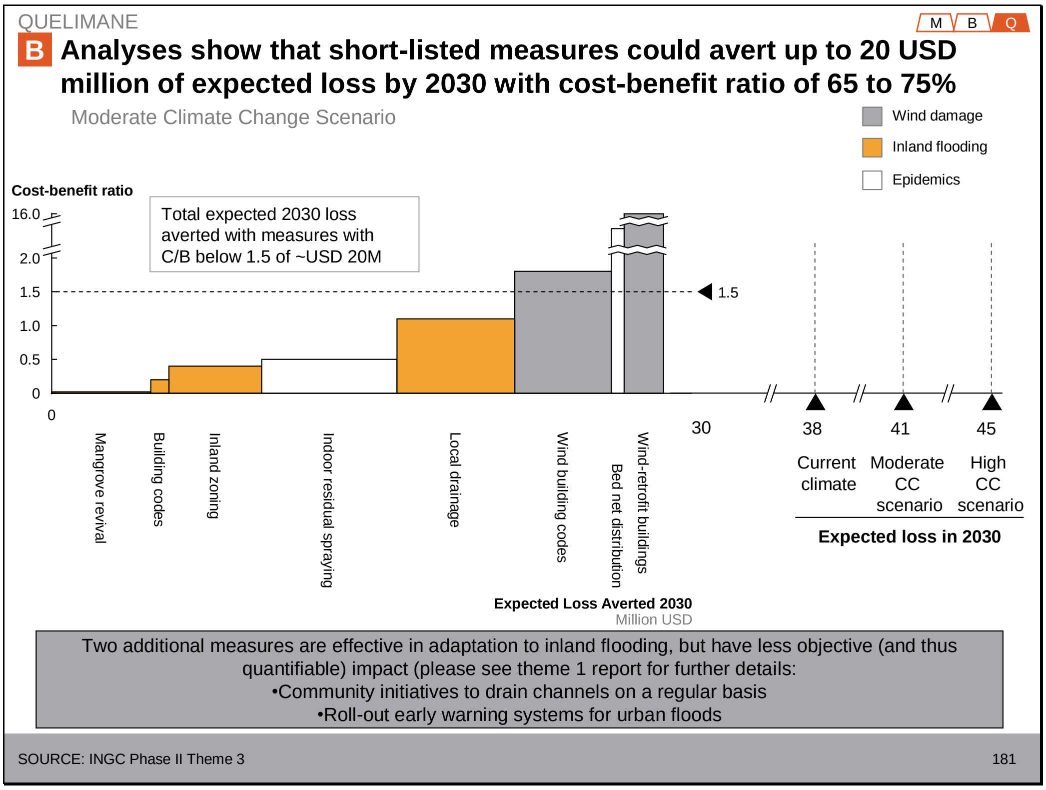
Risk-averse decision makers might accept a higher CBR

CBR of 1.5 used as a cutoff in Mozambique analysis because it is the typical CBR for retail insurance

Measures with CBR<1 are cost-effective in a risk-neutral environment

Reduction of the expected loss by implementing the measure

SLIDE 182



QUELIMANE

B Analyses show that short-listed measures could avert up to 20 USD million of expected loss by 2030 with cost-benefit ratio of 65 to 75%

Moderate Climate Change Scenario

Total expected 2030 loss averted with measures with C/B below 1.5 of ~USD 20M

Two additional measures are effective in adaptation to inland flooding, but have less objective (and thus quantifiable) impact (please see theme 1 report for further details:
•Community initiatives to drain channels on a regular basis
•Roll-out early warning systems for urban floods

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 182:

Response measures – Shortlist of adaptation measures module

Analyses show that short-listed measures could avert up to 20 USD millions of expected loss by 2030 with cost-benefit ration of 65 to 75%

This "cost curve" charts the most cost effective actions that Quelimane could take in order avoid climate-caused losses by 2030.

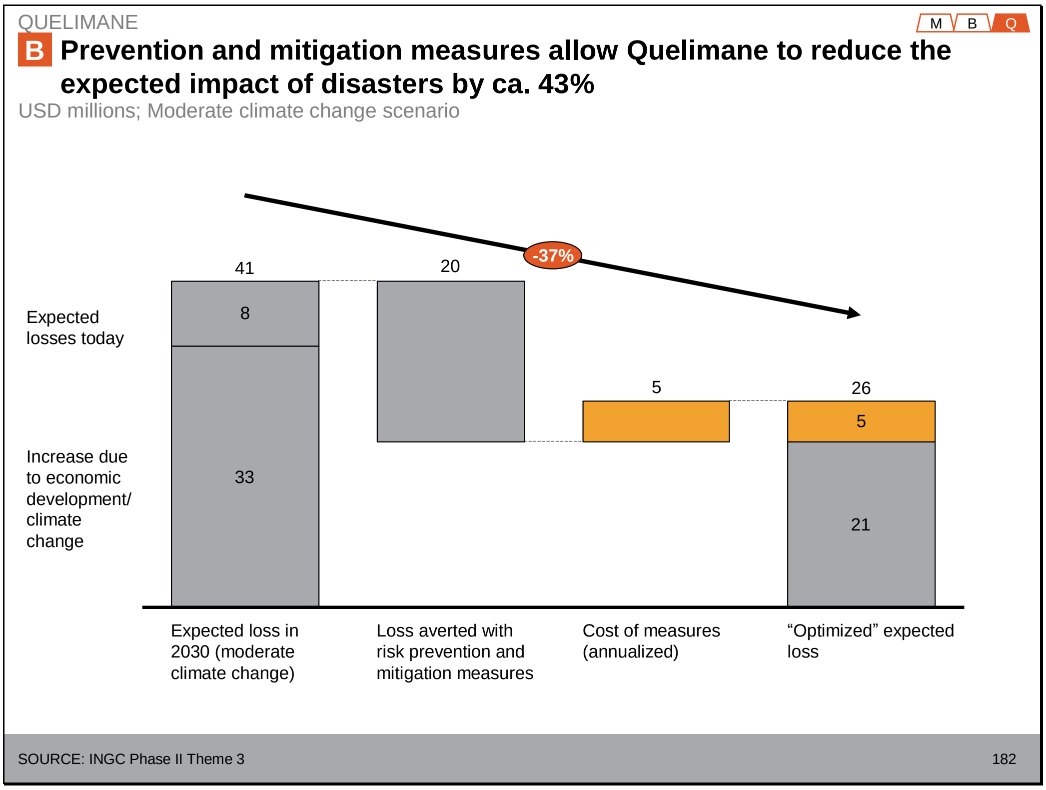
The x axis shows the expected losses that will be incurred by Quelimane by 2030. The three lines all the way to the right are the total expected losses under the three climate scenarios – Current Climate, Moderate CC and High CC.

The width of each bar on the cost curve represents the losses that would be avoided if the measure was put into place. Land drainage, for example, would avoid the most losses of all the measures. The bars are colored according to the type of risk the measure helps avoid (e.g., orange for inland flooding).

The y axis is the cost-benefit ratio for each measure, meaning how much the measure costs to implement relative to the benefits (the avoided costs from climate change) it produces. Measures with a C/B ratio of less than 1 produce more benefit than they cost. The bars are sorted in order of increasing cost to benefit, meaning that the ones on the left produce the most benefit for their cost while the ones to the right produce the least benefit for the most cost.

This curve notes the Expected Loss Averted by 2030 at USD 20 M, the sum of the costs avoided (the width of the bar) of all measures with a C/B Ratio less than 1.5, the proposed cut-off point for implementing a measure. The average of C/B ratios of the implemented measures is show to be 65 – 75%.

SLIDE 183



QUELIMANE

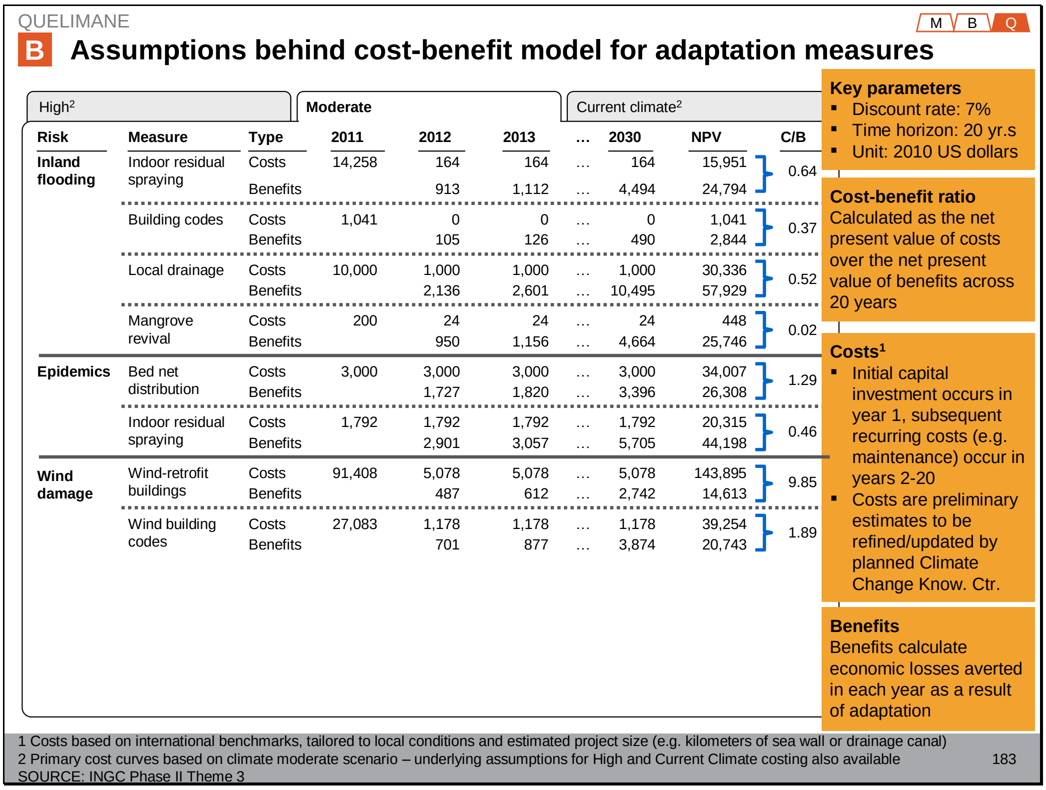
M B Q

B Prevention and mitigation measures allow Quelimane to reduce the expected impact of disasters by ca. 43%

USD millions; Moderate climate change scenario

SOURCE: INGC Phase II Theme 3

SLIDE 184



QUELIMANE

M B Q

B Assumptions behind cost-benefit model for adaptation measures

High[2] | **Moderate** | Current climate[2]

Risk	Measure	Type	2011	2012	2013	…	2030	NPV	C/B
Inland flooding	Indoor residual spraying	Costs	14,258	164	164	…	164	15,951	0.64
		Benefits		913	1,112	…	4,494	24,794	
	Building codes	Costs	1,041	0	0	…	0	1,041	0.37
		Benefits		105	126	…	490	2,844	
	Local drainage	Costs	10,000	1,000	1,000	…	1,000	30,336	0.52
		Benefits		2,136	2,601	…	10,495	57,929	
	Mangrove revival	Costs	200	24	24	…	24	448	0.02
		Benefits		950	1,156	…	4,664	25,746	
Epidemics	Bed net distribution	Costs	3,000	3,000	3,000	…	3,000	34,007	1.29
		Benefits		1,727	1,820	…	3,396	26,308	
	Indoor residual spraying	Costs	1,792	1,792	1,792	…	1,792	20,315	0.46
		Benefits		2,901	3,057	…	5,705	44,198	
Wind damage	Wind-retrofit buildings	Costs	91,408	5,078	5,078	…	5,078	143,895	9.85
		Benefits		487	612	…	2,742	14,613	
	Wind building codes	Costs	27,083	1,178	1,178	…	1,178	39,254	1.89
		Benefits		701	877	…	3,874	20,743	

Key parameters
- Discount rate: 7%
- Time horizon: 20 yr.s
- Unit: 2010 US dollars

Cost-benefit ratio
Calculated as the net present value of costs over the net present value of benefits across 20 years

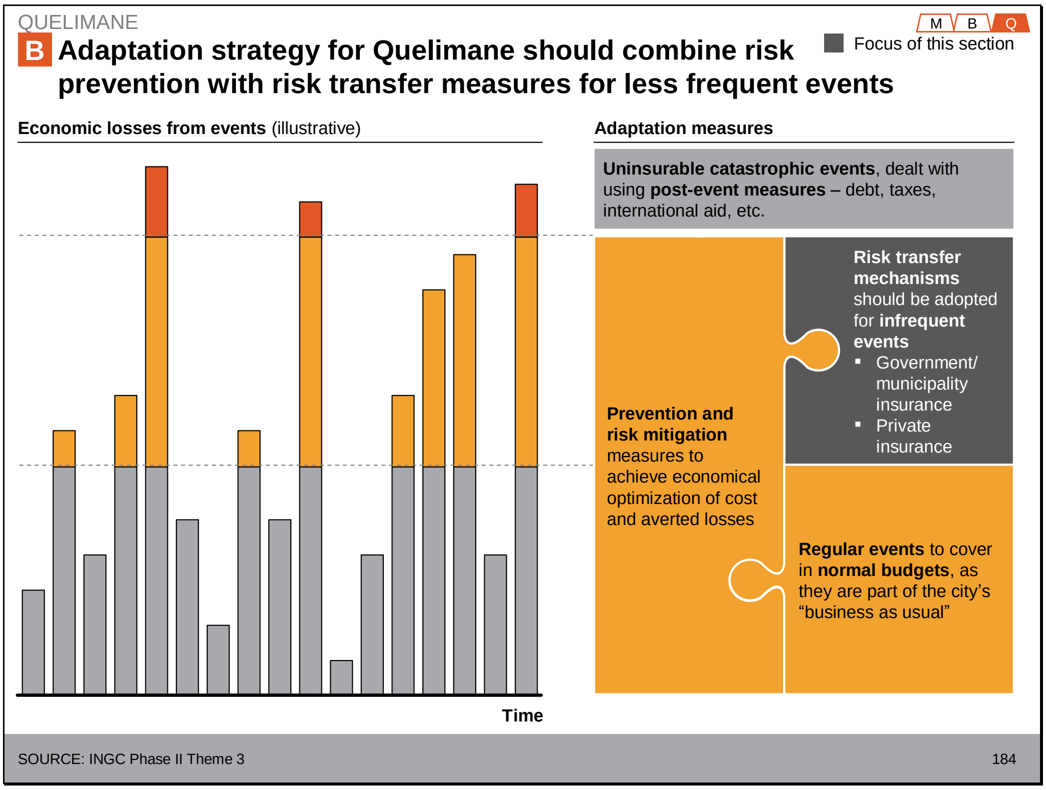
Costs[1]
- Initial capital investment occurs in year 1, subsequent recurring costs (e.g. maintenance) occur in years 2-20
- Costs are preliminary estimates to be refined/updated by planned Climate Change Know. Ctr.

Benefits
Benefits calculate economic losses averted in each year as a result of adaptation

[1] Costs based on international benchmarks, tailored to local conditions and estimated project size (e.g. kilometers of sea wall or drainage canal)
[2] Primary cost curves based on climate moderate scenario – underlying assumptions for High and Current Climate costing also available

SOURCE: INGC Phase II Theme 3

SLIDE 185



QUELIMANE

B Adaptation strategy for Quelimane should combine risk prevention with risk transfer measures for less frequent events

Economic losses from events (illustrative)

Adaptation measures

Uninsurable catastrophic events, dealt with using **post-event measures** – debt, taxes, international aid, etc.

Risk transfer mechanisms should be adopted for **infrequent events**

- Government/ municipality insurance
- Private insurance

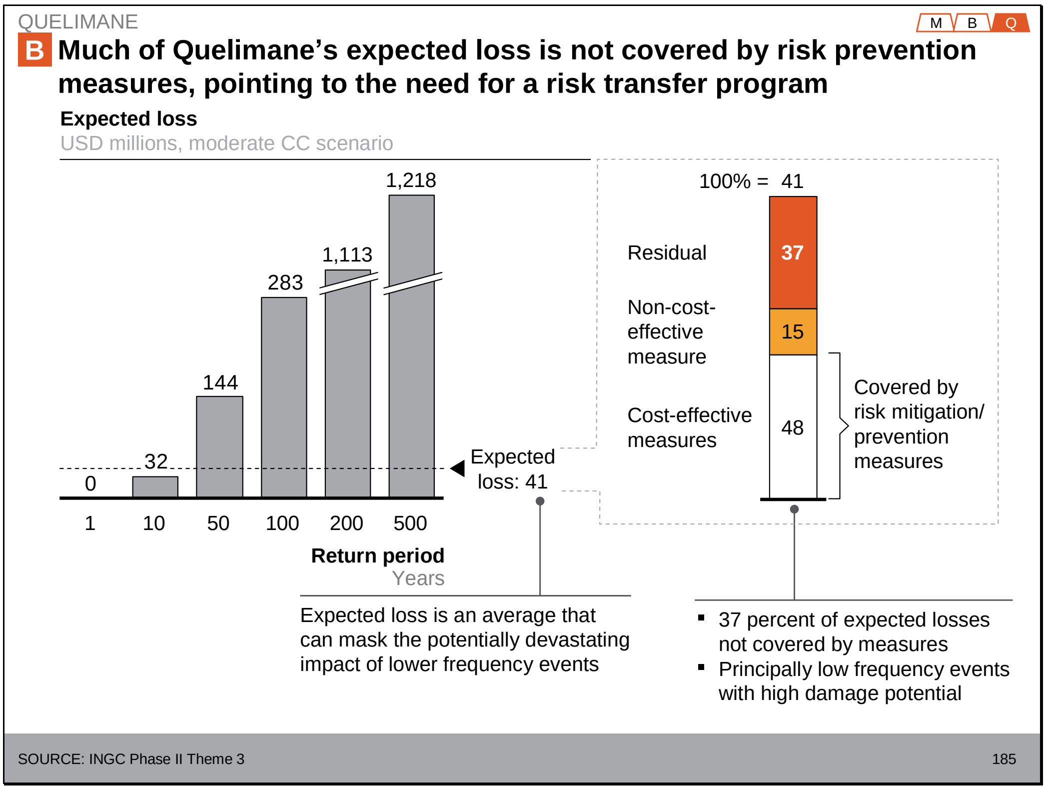
Prevention and risk mitigation measures to achieve economical optimization of cost and averted losses

Regular events to cover in **normal budgets**, as they are part of the city's "business as usual"

SOURCE: INGC Phase II Theme 3

184

SLIDE 186



QUELIMANE

B Much of Quelimane's expected loss is not covered by risk prevention measures, pointing to the need for a risk transfer program

Expected loss

USD millions, moderate CC scenario

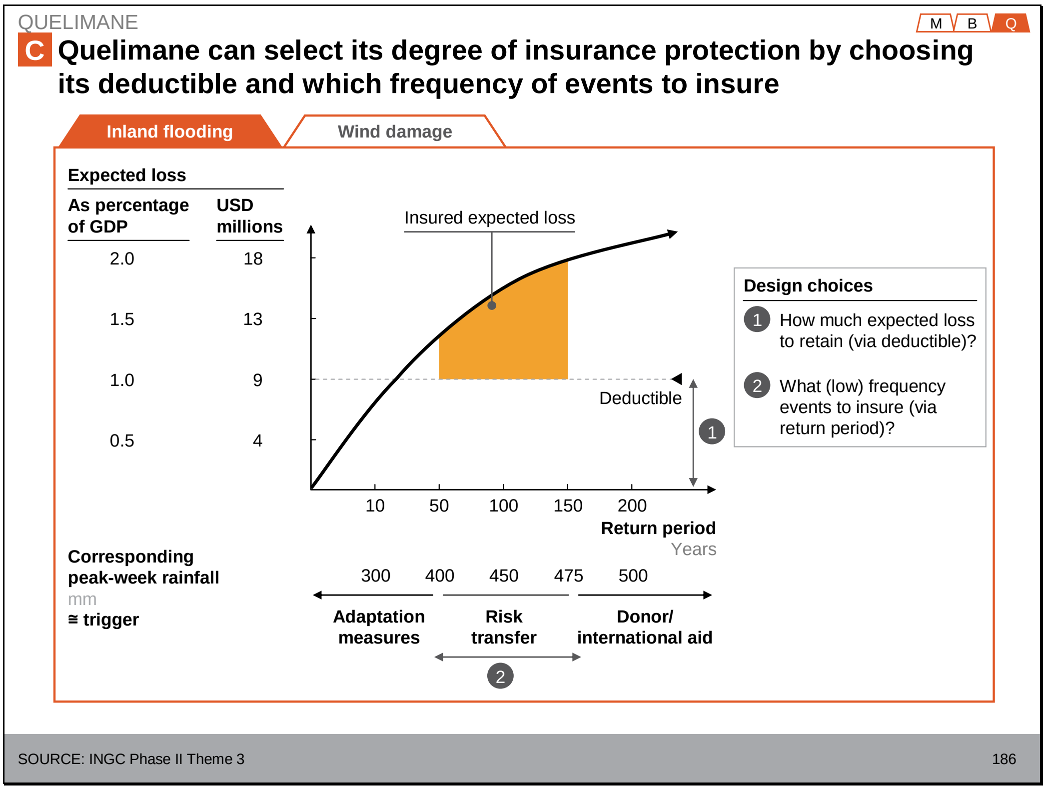
Expected loss is an average that can mask the potentially devastating impact of lower frequency events

- 37 percent of expected losses not covered by measures
- Principally low frequency events with high damage potential

SOURCE: INGC Phase II Theme 3

185

SLIDE 187



QUELIMANE

M B Q

C Quelimane can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

Design choices

1. How much expected loss to retain (via deductible)?
2. What (low) frequency events to insure (via return period)?

SOURCE: INGC Phase II Theme 3

186

NOTES FOR SLIDE 187:

Possible Adaptation Responses – Insurance Program Proposal module

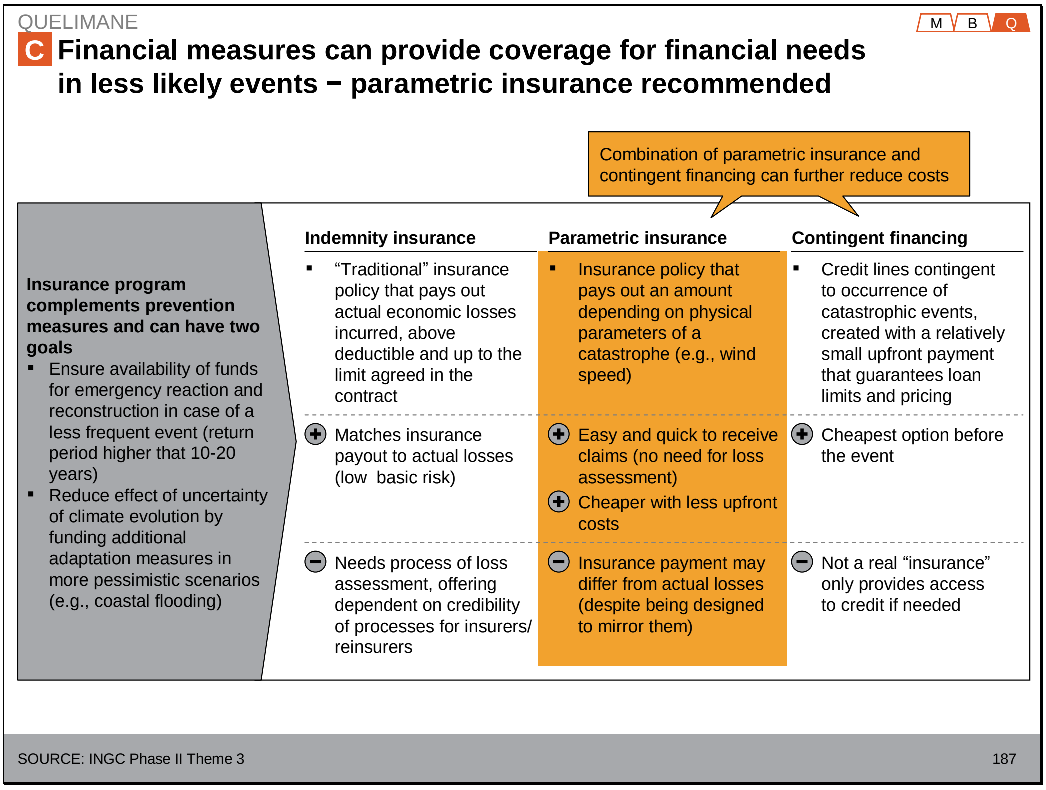
Quelimade can select its degree of insurance protection by choosing its deductible and which frequency of events to insure

This chart plots the return period of a catastrophe (how often it occurs) against the expected loss from the event.

Quelimade can avoid the damages of events occurring with a relatively high frequency cost-effectively through adaptation measures. On the other end of the spectrum, there are events that occur only every several hundred years for which the municipality will need to rely on donor and international support.

In the middle of the spectrum are low probability, high impact events for which the municipality may want to transfer risk using a financial mechanism, e.g., an insurance policy. The municipality will need to determine how much risk to maintain on itself for these events, e.g., how high to set its deductible. As well, it must determine the range of events to cover with a risk transfer, e.g., events occurring ever 50 - 100 years, versus those occurring every 100 – 150 years.

SLIDE 188



QUELIMANE

M B Q

C Financial measures can provide coverage for financial needs in less likely events – parametric insurance recommended

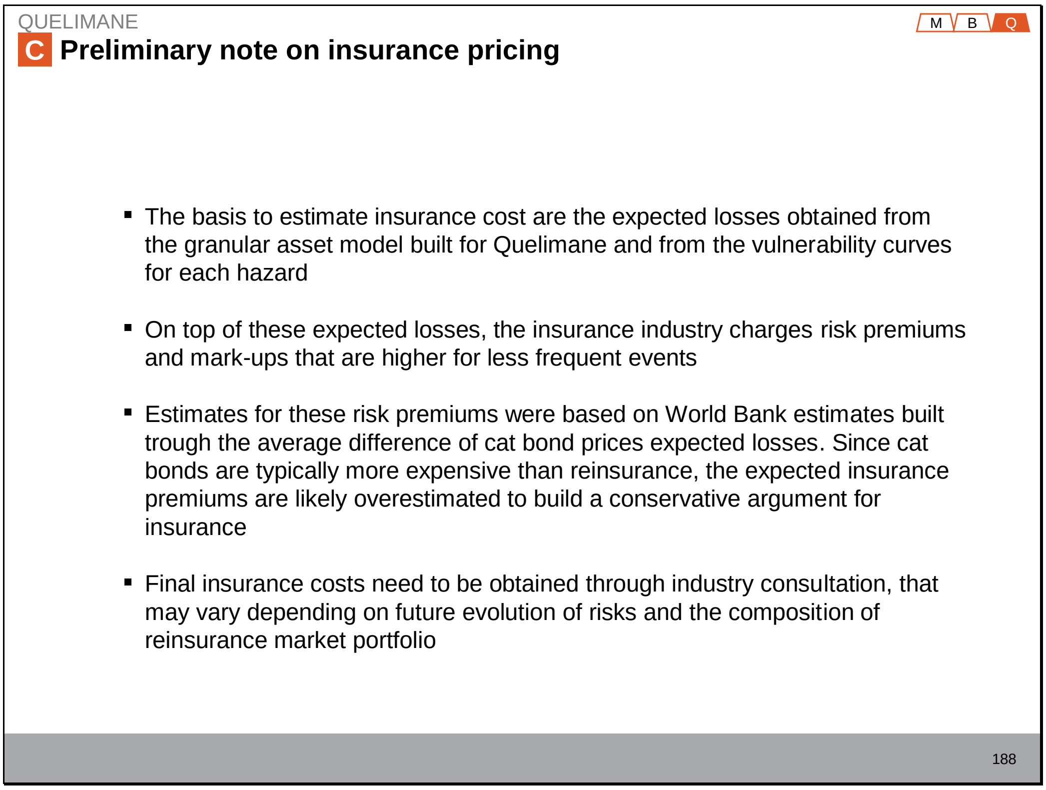
Combination of parametric insurance and contingent financing can further reduce costs

Insurance program complements prevention measures and can have two goals
- Ensure availability of funds for emergency reaction and reconstruction in case of a less frequent event (return period higher that 10-20 years)
- Reduce effect of uncertainty of climate evolution by funding additional adaptation measures in more pessimistic scenarios (e.g., coastal flooding)

	Indemnity insurance	**Parametric insurance**	**Contingent financing**
▪	"Traditional" insurance policy that pays out actual economic losses incurred, above deductible and up to the limit agreed in the contract	Insurance policy that pays out an amount depending on physical parameters of a catastrophe (e.g., wind speed)	Credit lines contingent to occurrence of catastrophic events, created with a relatively small upfront payment that guarantees loan limits and pricing
⊕	Matches insurance payout to actual losses (low basic risk)	Easy and quick to receive claims (no need for loss assessment) ⊕ Cheaper with less upfront costs	Cheapest option before the event
⊖	Needs process of loss assessment, offering dependent on credibility of processes for insurers/ reinsurers	Insurance payment may differ from actual losses (despite being designed to mirror them)	Not a real "insurance" only provides access to credit if needed

SOURCE: INGC Phase II Theme 3

SLIDE 189



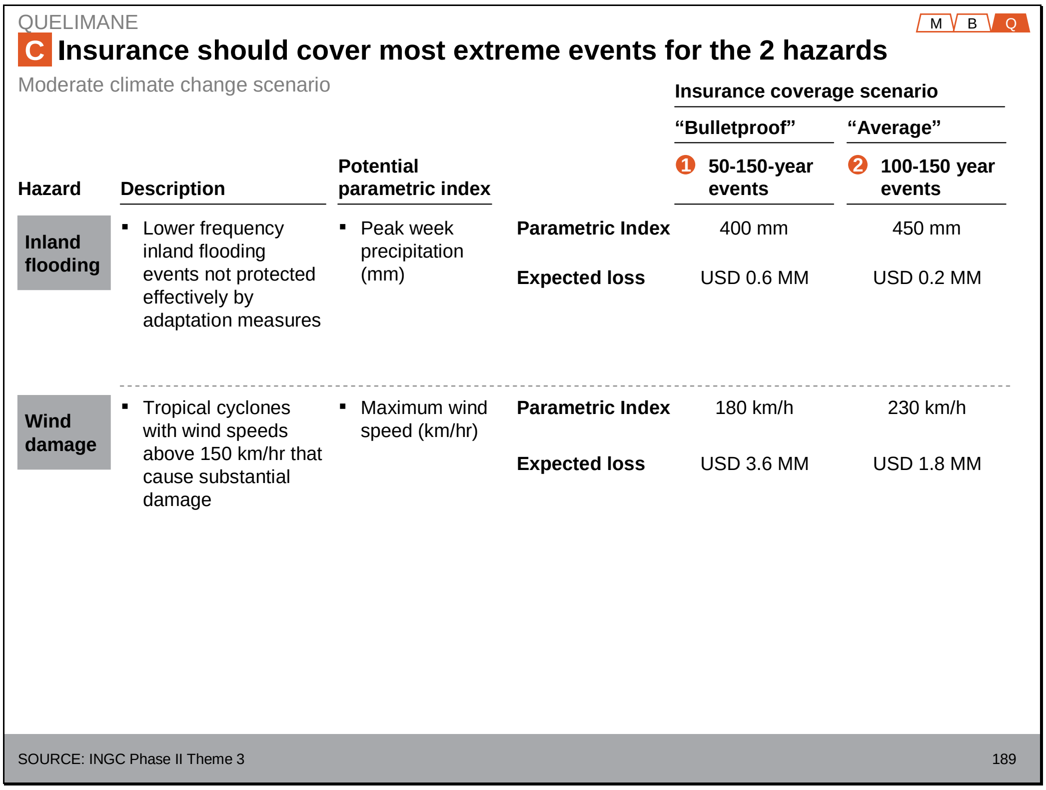
QUELIMANE

M B Q

C Preliminary note on insurance pricing

- The basis to estimate insurance cost are the expected losses obtained from the granular asset model built for Quelimane and from the vulnerability curves for each hazard
- On top of these expected losses, the insurance industry charges risk premiums and mark-ups that are higher for less frequent events
- Estimates for these risk premiums were based on World Bank estimates built trough the average difference of cat bond prices expected losses. Since cat bonds are typically more expensive than reinsurance, the expected insurance premiums are likely overestimated to build a conservative argument for insurance
- Final insurance costs need to be obtained through industry consultation, that may vary depending on future evolution of risks and the composition of reinsurance market portfolio

SLIDE 190



QUELIMANE

M B Q

C Insurance should cover most extreme events for the 2 hazards

Moderate climate change scenario

				Insurance coverage scenario	
				“Bulletproof”	“Average”
Hazard	**Description**	**Potential parametric index**		❶ **50-150-year events**	❷ **100-150 year events**
Inland flooding	▪ Lower frequency inland flooding events not protected effectively by adaptation measures	▪ Peak week precipitation (mm)	**Parametric Index**	400 mm	450 mm
			Expected loss	USD 0.6 MM	USD 0.2 MM
Wind damage	▪ Tropical cyclones with wind speeds above 150 km/hr that cause substantial damage	▪ Maximum wind speed (km/hr)	**Parametric Index**	180 km/h	230 km/h
			Expected loss	USD 3.6 MM	USD 1.8 MM

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 190:

Possible Adaptation Responses – Insurance Program Proposal module

Insurance should cover most extreme events for the 2 hazards

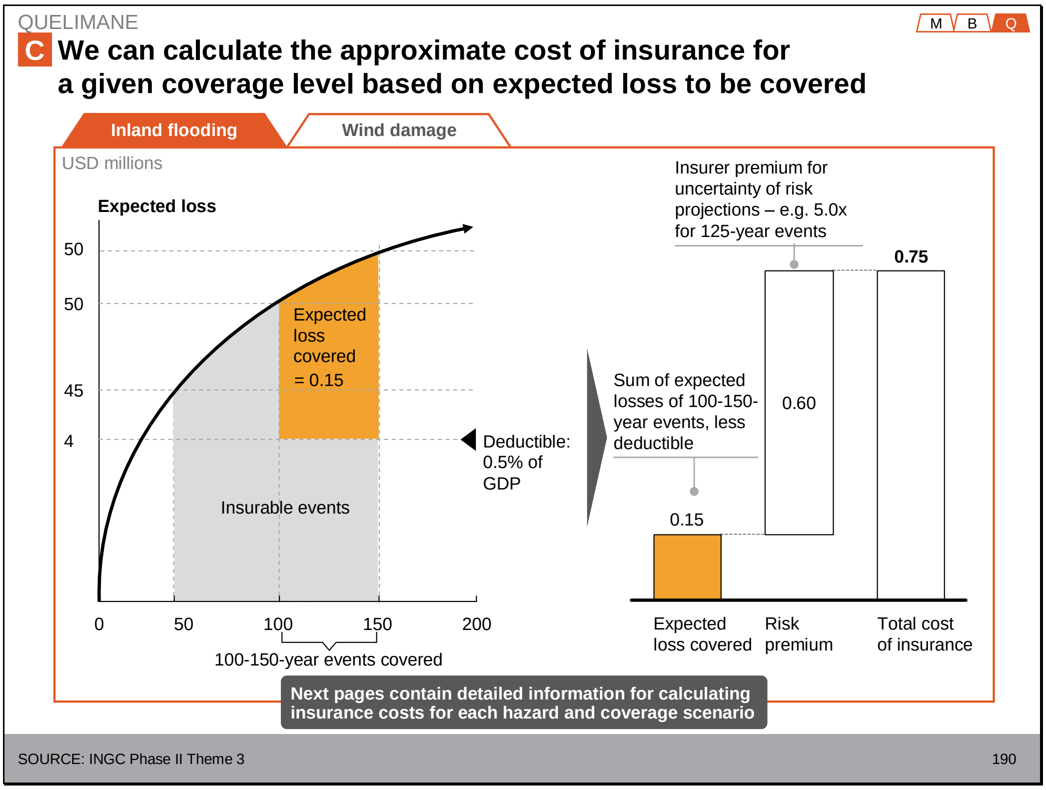
Quelimane could purchase insurance to protect itself against catastrophic losses associated with two major climate events.

Two levels of insurance are described, a “bulletproof” policy level that would cover the municipality against severe events projected to occur only every 50-150 years, and an “average” policy level that would only cover the events projected to occur once every 100-150 years.

For each level of insurance and each event type, a “parametric index” is listed, meaning an event that would trigger an automatic payout of the insurance coverage. For example, for the “bulletproof” policy for inland flooding, the insurance would pay out automatically when peak week precipitation reaches 400mm.

Expected losses are also listed for each policy level – the losses are greater for the bulletproof policies because, while the triggering events are on average less severe for the 50-150 year events, they also are projected to occur more often.

SLIDE 191



QUELIMANE

C We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

Next pages contain detailed information for calculating insurance costs for each hazard and coverage scenario

SOURCE: INGC Phase II Theme 3

190

NOTES FOR SLIDE 191:

Possible Adaptation Responses – Insurance Program Proposal module

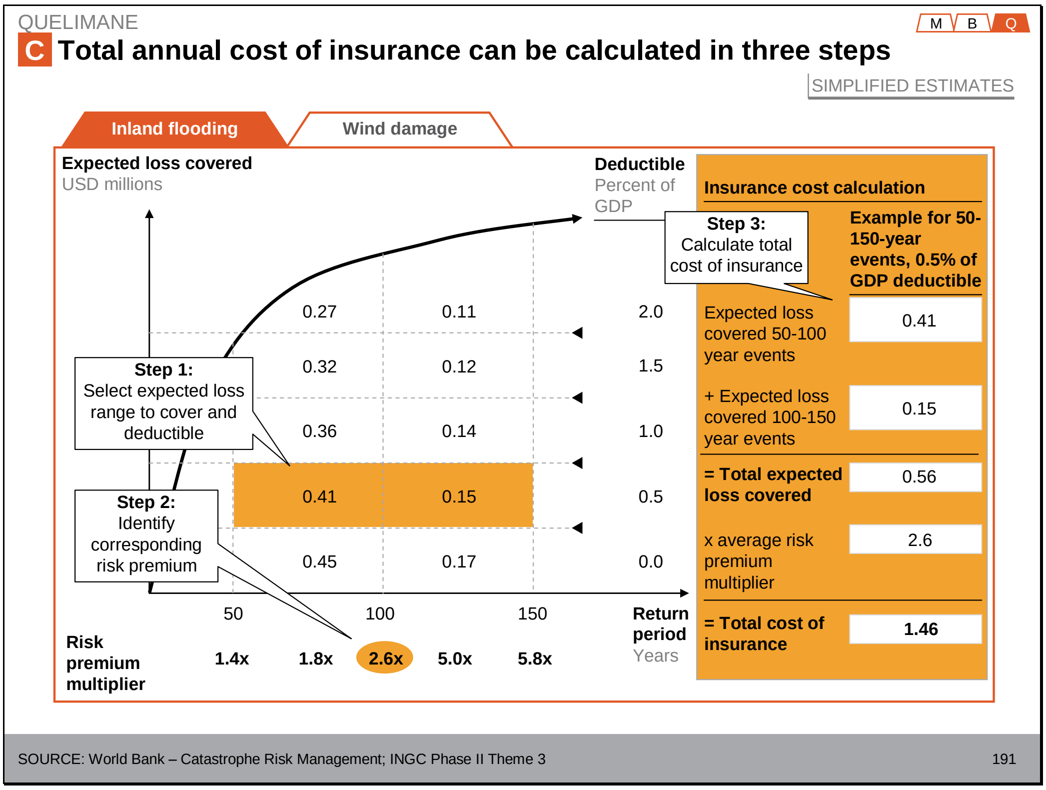
We can calculate the approximate cost of insurance for a given coverage level based on expected loss to be covered

First, the municipality needs to determine the range of expected loss to cover, which is a function of the range of insurable events covered by the policy, and the deductible under which the municipality will cover costs itself.

In this example, the range of events covered for inland flooding is shown to be 100-150 year events, and the municipality has agreed to a deductible of 0.5% of it's GDP, meaning that the insurance policy will only cover losses above that level. This means that the insurer will be covering the amount between the deductible and the total expected loss for that range of events, which translates to a USD 0.15 M annual insurance premium for the coverage.

Given that expected loss coverage, an estimate for the total cost of the insurance is possible. Because of the uncertainty of predictions required for these events, insurers will charge a "risk premium" that is some multiple of the expected loss covered. In this case, the risk premium multiplier for ~125 year events is ~5.0x, for a risk premium of 0.60 M. This is added to the expected loss covered to produced a total cost of insurance of 0.76 M.

SLIDE 192



QUELIMANE

C Total annual cost of insurance can be calculated in three steps

SIMPLIFIED ESTIMATES

Expected loss covered
USD millions

Deductible
Percent of GDP

0.27	0.11	2.0
0.32	0.12	1.5
0.36	0.14	1.0
0.41	0.15	0.5
0.45	0.17	0.0

Return period
Years

	50		100		150
Risk premium multiplier	**1.4x**	**1.8x**	**2.6x**	**5.0x**	**5.8x**

Step 1: Select expected loss range to cover and deductible

Step 2: Identify corresponding risk premium

Step 3: Calculate total cost of insurance

Insurance cost calculation

	Example for 50-150-year events, 0.5% of GDP deductible
Expected loss covered 50-100 year events	0.41
+ Expected loss covered 100-150 year events	0.15
= Total expected loss covered	0.56
x average risk premium multiplier	2.6
= Total cost of insurance	**1.46**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

NOTES FOR SLIDE 192:

Possible Adaptation Responses – Insurance Program Proposal module

Total annual cost of insurance can be calculated in three steps

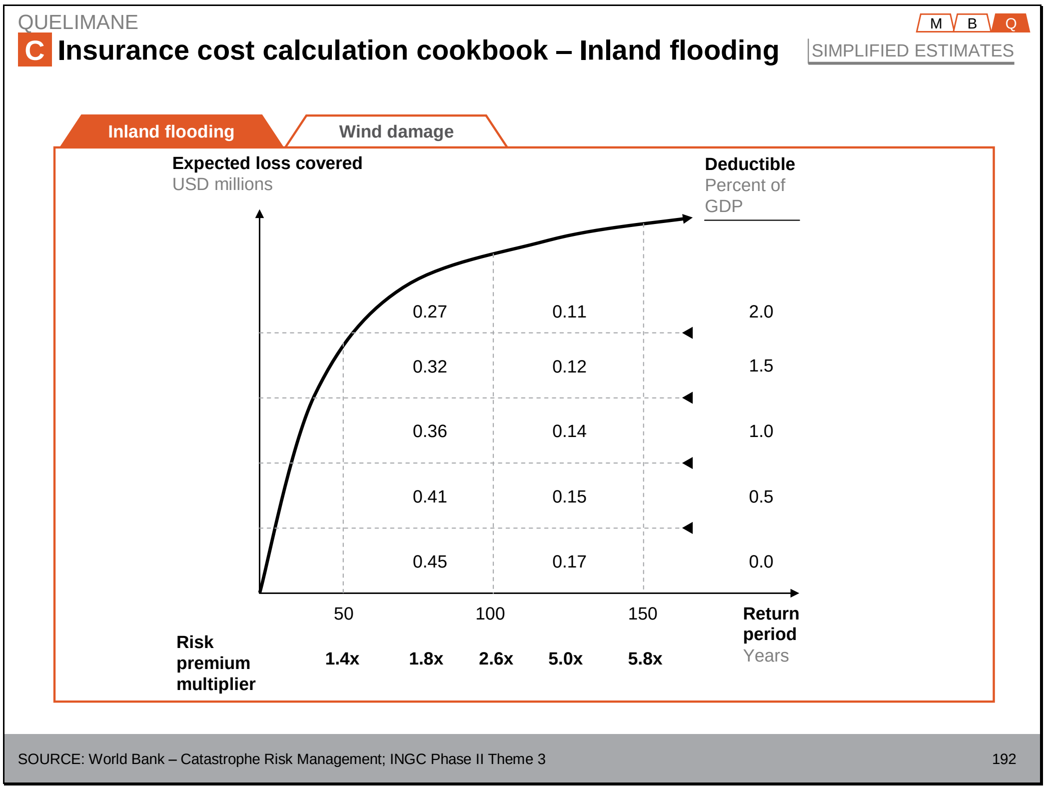
This page displays a more detailed explanation of the total cost of insurance concept from the previous page.

The first step shown is to select a range of events to cover, and a deductible under which the municipality will cover itself.

The second step is to identify the risk premium multiplier that corresponds with that coverage range.

The third step is to calculate the total cost of insurance by multiplying the total expected loss covered by the risk premium multiplier to get the risk premium. The total expected loss covered and the risk premium are then added together to generate the total cost of insurance.

SLIDE 193



QUELIMANE

C **Insurance cost calculation cookbook – Inland flooding**

SIMPLIFIED ESTIMATES

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

192

NOTES FOR SLIDE 193:

Possible Adaptation Responses – Insurance Program Proposal module

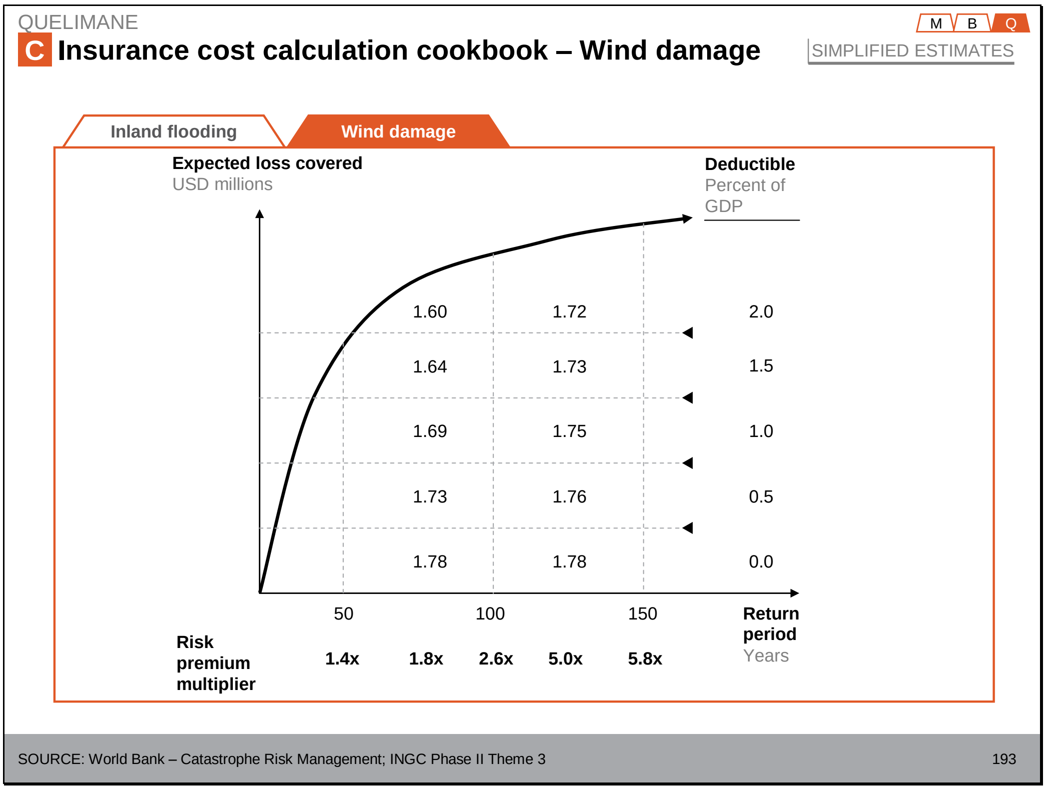
Insurance cost calculation cookbook – Inland flooding

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Quelimane in considering it's likely insurance cost for inland flooding.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 194



QUELIMANE

C **Insurance cost calculation cookbook – Wind damage**

M B Q

SIMPLIFIED ESTIMATES

Inland flooding | **Wind damage**

Expected loss covered
USD millions

Deductible
Percent of GDP

1.60	1.72	2.0
1.64	1.73	1.5
1.69	1.75	1.0
1.73	1.76	0.5
1.78	1.78	0.0

Return period
Years

Risk premium multiplier **1.4x** **1.8x** **2.6x** **5.0x** **5.8x**

SOURCE: World Bank – Catastrophe Risk Management; INGC Phase II Theme 3

193

NOTES FOR SLIDE 194:

Possible Adaptation Responses – Insurance Program Proposal module

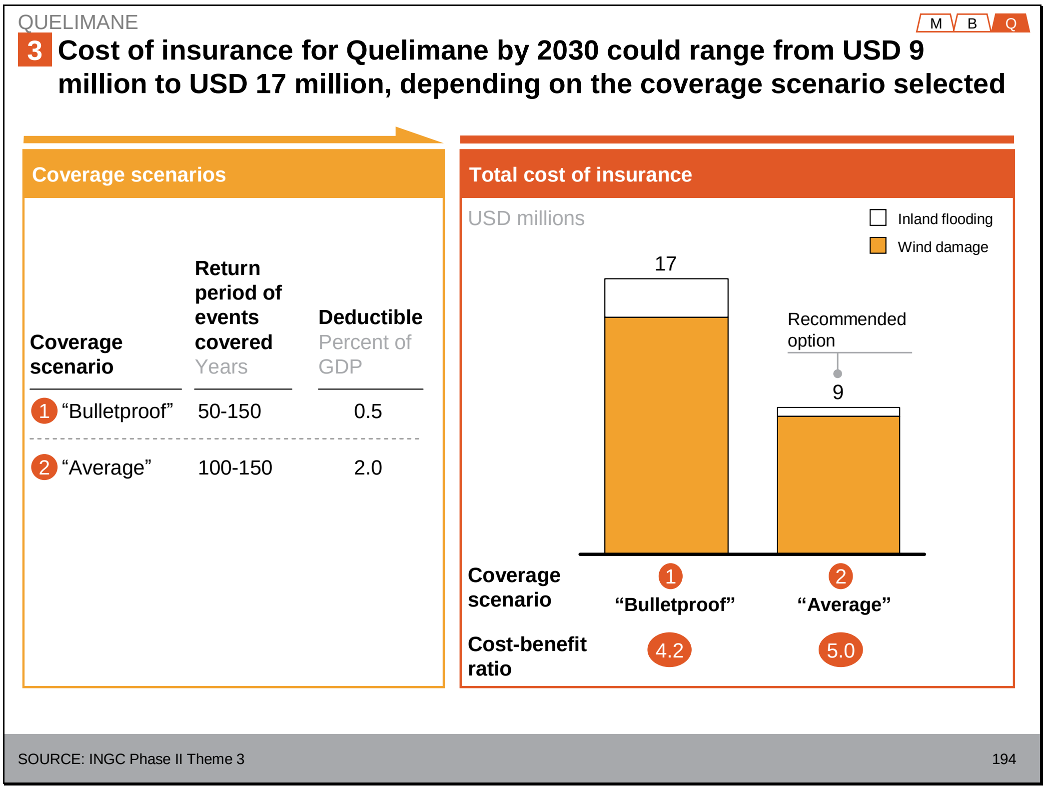
Insurance cost calculation cookbook – wind damage

Using data on projected return periods for different loss level events by hazard type, we have constructed a playbook for Quelimane in considering it's likely insurance cost for wind damage.

Using the same methodology described on previous pages, the municipality can use this curve to determine its preferred range of coverage and deductible, identify the loss covered and the risk premium multiplier, and calculate the total cost of insurance.

This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage.

SLIDE 195



QUELIMANE

M B Q

3 Cost of insurance for Quelimane by 2030 could range from USD 9 million to USD 17 million, depending on the coverage scenario selected

Coverage scenarios

Coverage scenario	**Return period of events covered** Years	**Deductible** Percent of GDP
① "Bulletproof"	50-150	0.5
② "Average"	100-150	2.0

Total cost of insurance

USD millions

☐ Inland flooding
🟧 Wind damage

Coverage scenario	① **"Bulletproof"**	② **"Average"**
Cost-benefit ratio	4.2	5.0

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 195:

Possible Adaptation Responses – Insurance Program Proposal module

Cost of insurance for Quelimane by 2030 could range from USD 9 million to USD 17 million, depending on the coverage scenario selected

Two different coverage scenarios are described here. The first (the "bulletproof") has a wider range of events covered (50-150 year events), and a lower deductible – 0.5% of GDP. The second (the "average") chooses a narrower range of events to cover (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks for each hazard type on the previous pages to calculate the total cost of insurance, the annual costs were identified and added in the bars on the right for each scenario.

Lastly, the Cost-benefit ratios were calculated for each insurance policy, showing the amount paid for the policy divided by the estimated payouts. Because of the large risk premiums for these policies, the cost benefit ratios for both coverage scenarios are quite poor (meaning much greater than 1), particularly when compared with other direct prevention measures.

SLIDE 196

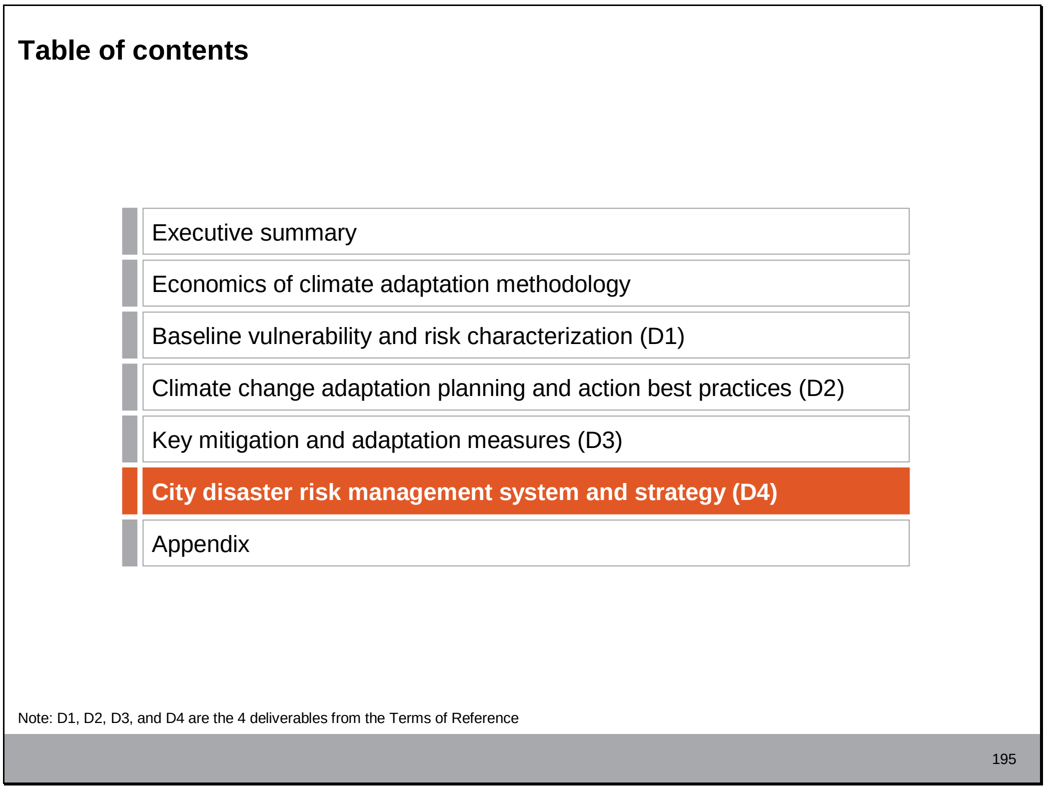
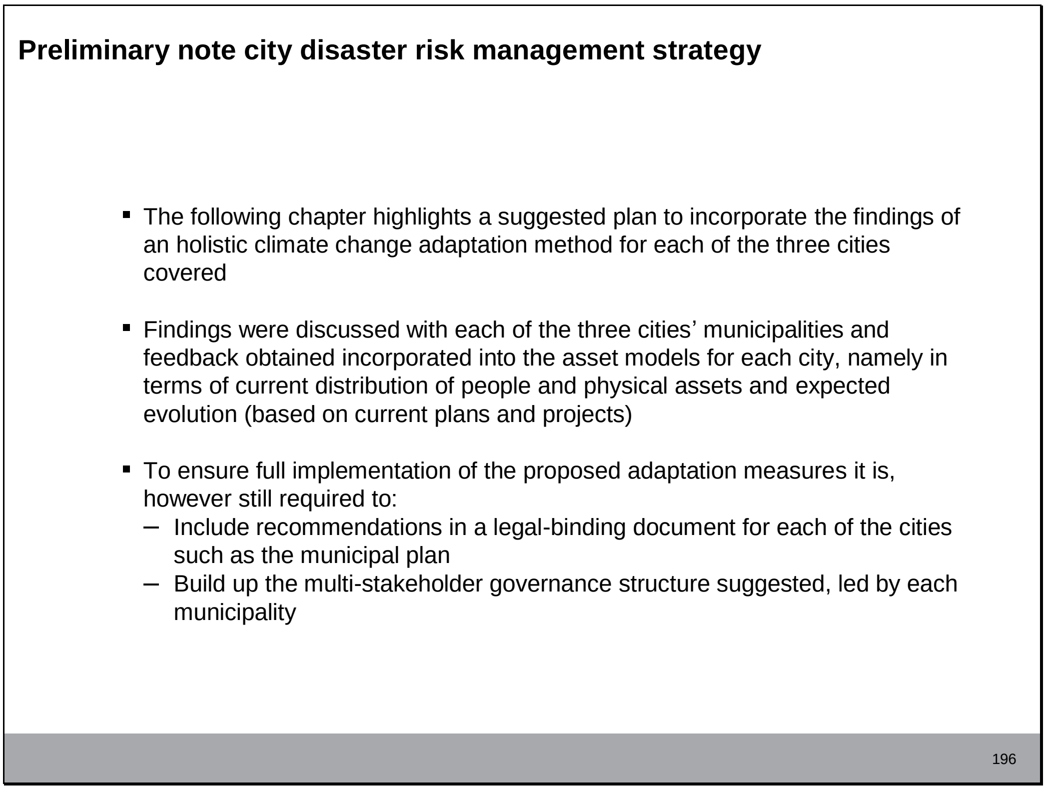


Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

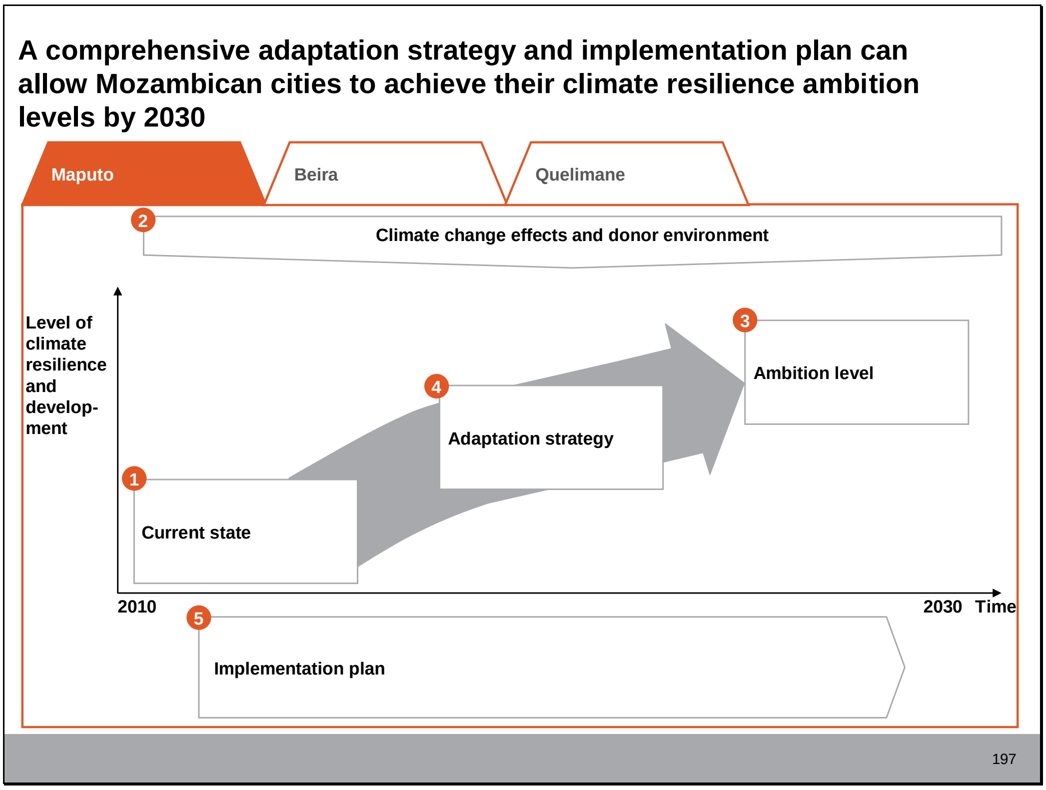
SLIDE 197



Preliminary note city disaster risk management strategy

- The following chapter highlights a suggested plan to incorporate the findings of an holistic climate change adaptation method for each of the three cities covered
- Findings were discussed with each of the three cities' municipalities and feedback obtained incorporated into the asset models for each city, namely in terms of current distribution of people and physical assets and expected evolution (based on current plans and projects)
- To ensure full implementation of the proposed adaptation measures it is, however still required to:
  - Include recommendations in a legal-binding document for each of the cities such as the municipal plan
  - Build up the multi-stakeholder governance structure suggested, led by each municipality

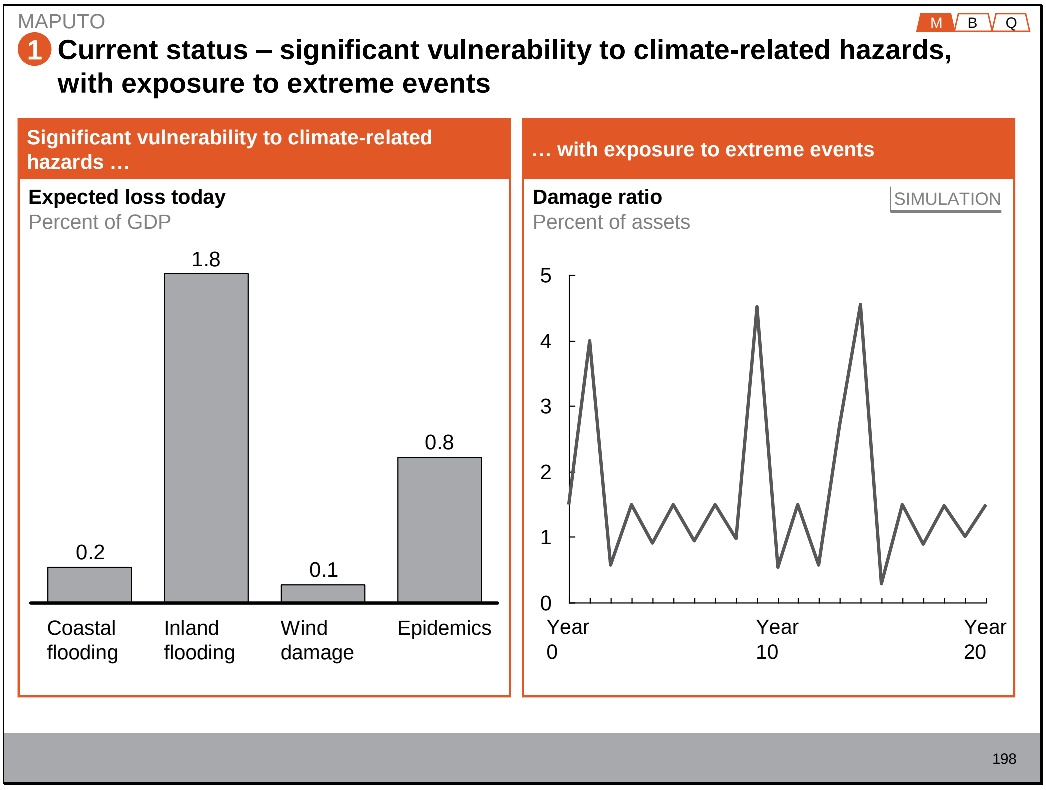
SLIDE 198



A comprehensive adaptation strategy and implementation plan can allow Mozambican cities to achieve their climate resilience ambition levels by 2030

Maputo | Beira | Quelimane

SLIDE 199



MAPUTO

M | B | Q

① Current status – significant vulnerability to climate-related hazards, with exposure to extreme events

Significant vulnerability to climate-related hazards …

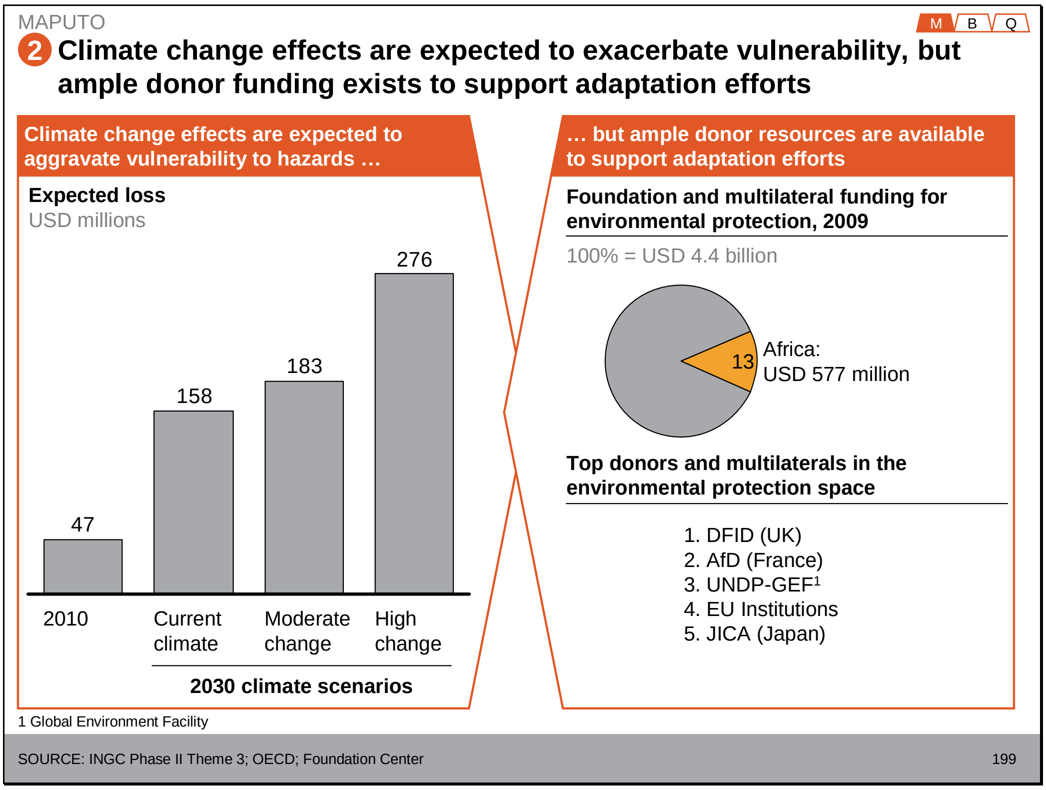
Expected loss today
Percent of GDP

… with exposure to extreme events

Damage ratio
Percent of assets

SIMULATION

SLIDE 200



MAPUTO

② Climate change effects are expected to exacerbate vulnerability, but ample donor funding exists to support adaptation efforts

Climate change effects are expected to aggravate vulnerability to hazards …

Expected loss
USD millions

2030 climate scenarios

… but ample donor resources are available to support adaptation efforts

Foundation and multilateral funding for environmental protection, 2009

100% = USD 4.4 billion

Africa:
USD 577 million

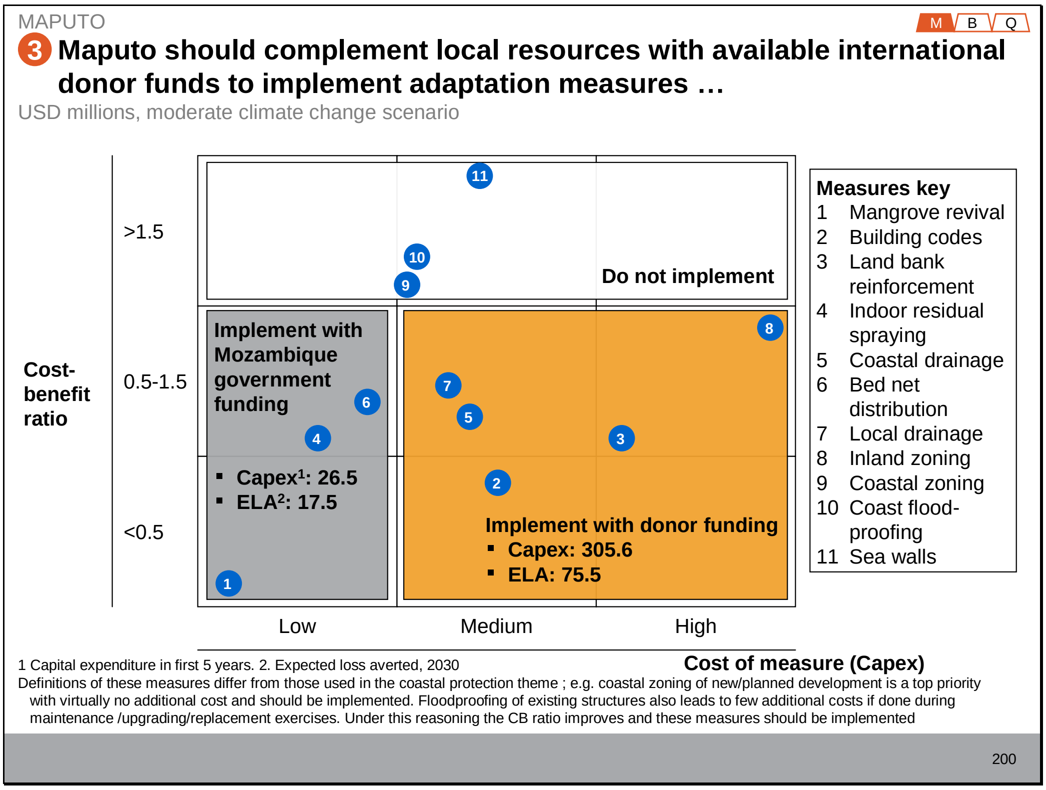
Top donors and multilaterals in the environmental protection space

1. DFID (UK)
2. AfD (France)
3. UNDP-GEF[1]
4. EU Institutions
5. JICA (Japan)

1 Global Environment Facility

SOURCE: INGC Phase II Theme 3; OECD; Foundation Center

SLIDE 201



MAPUTO

③ Maputo should complement local resources with available international donor funds to implement adaptation measures …

USD millions, moderate climate change scenario

Do not implement

Implement with Mozambique government funding
- **Capex[1]: 26.5**
- **ELA[2]: 17.5**

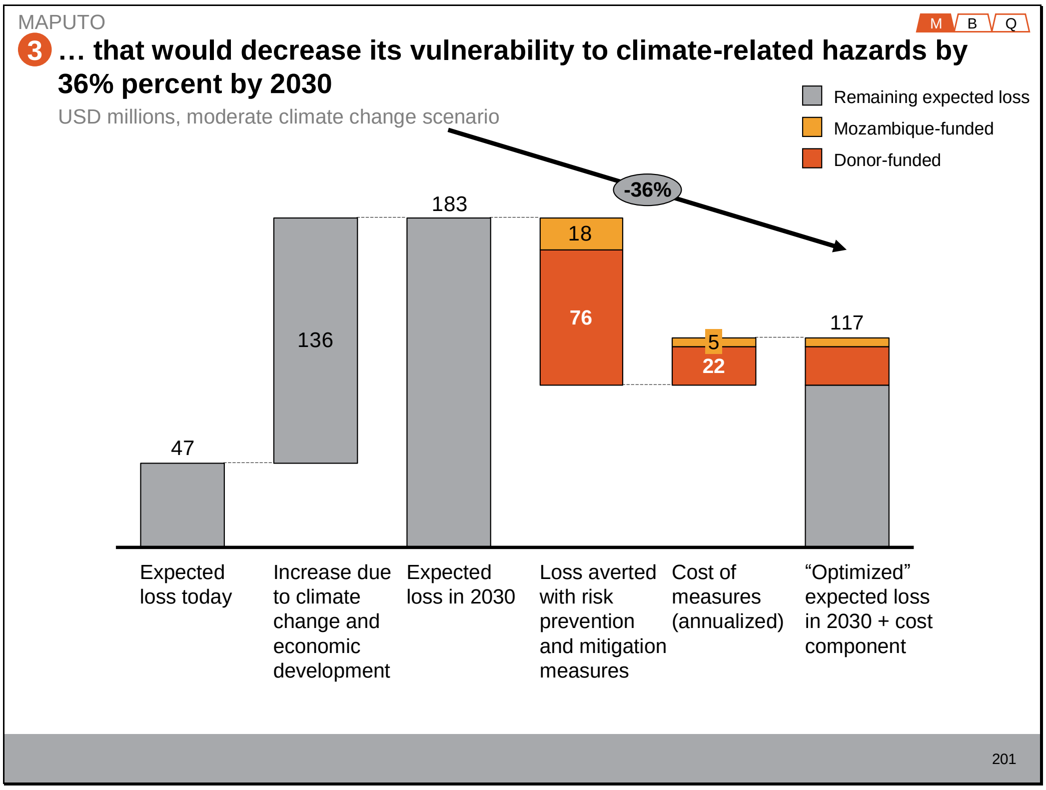
Implement with donor funding
- **Capex: 305.6**
- **ELA: 75.5**

Measures key

1	Mangrove revival
2	Building codes
3	Land bank reinforcement
4	Indoor residual spraying
5	Coastal drainage
6	Bed net distribution
7	Local drainage
8	Inland zoning
9	Coastal zoning
10	Coast flood-proofing
11	Sea walls

1 Capital expenditure in first 5 years. 2. Expected loss averted, 2030
Definitions of these measures differ from those used in the coastal protection theme ; e.g. coastal zoning of new/planned development is a top priority with virtually no additional cost and should be implemented. Floodproofing of existing structures also leads to few additional costs if done during maintenance /upgrading/replacement exercises. Under this reasoning the CB ratio improves and these measures should be implemented

SLIDE 202



MAPUTO

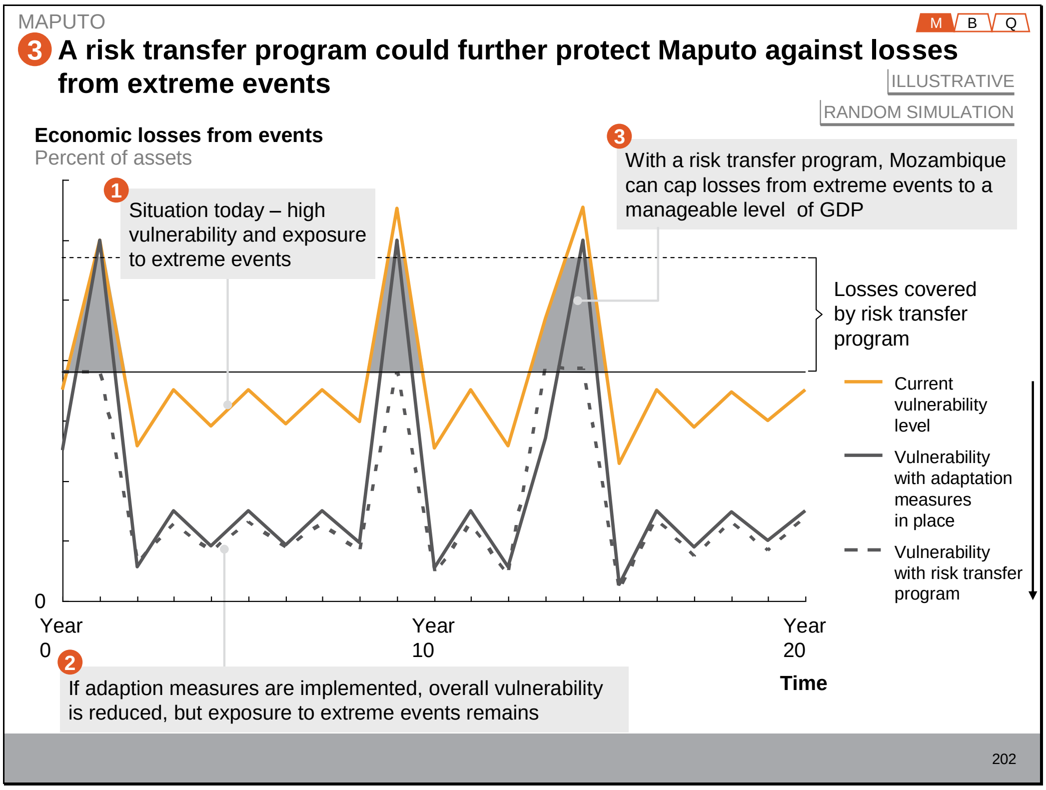
M B Q

③ … that would decrease its vulnerability to climate-related hazards by 36% percent by 2030

USD millions, moderate climate change scenario

201

SLIDE 203



MAPUTO

M B Q

③ A risk transfer program could further protect Maputo against losses from extreme events

ILLUSTRATIVE

RANDOM SIMULATION

Economic losses from events

Percent of assets

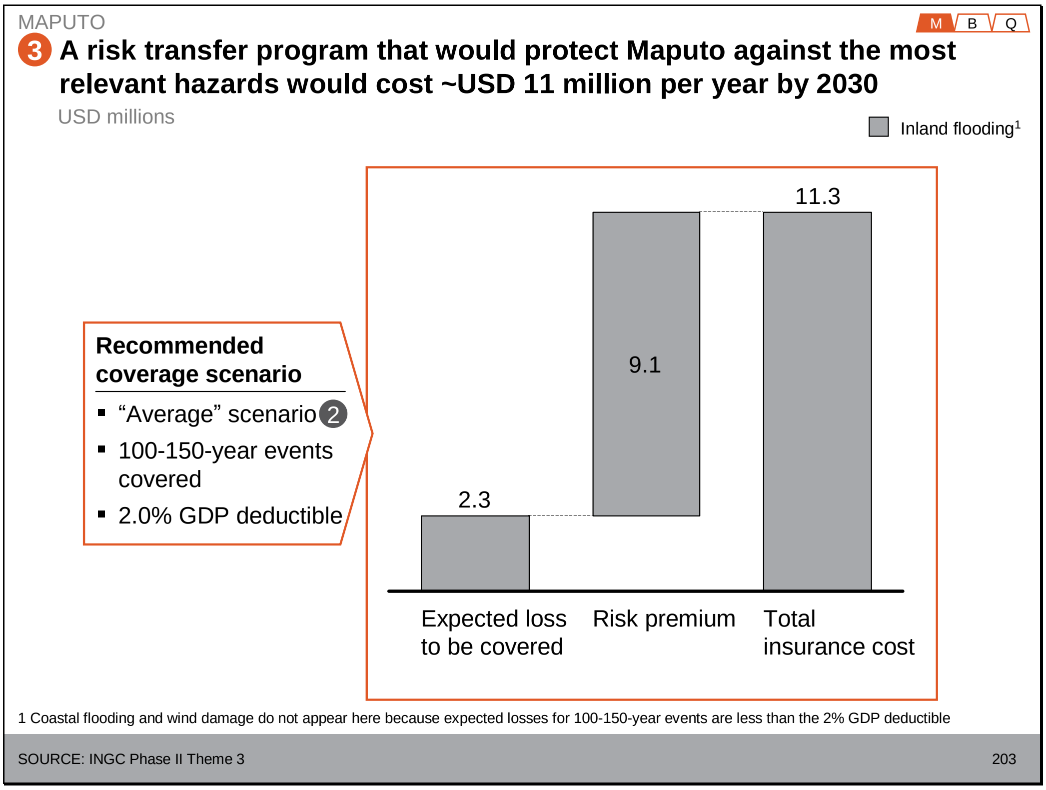
① Situation today – high vulnerability and exposure to extreme events

② If adaption measures are implemented, overall vulnerability is reduced, but exposure to extreme events remains

③ With a risk transfer program, Mozambique can cap losses from extreme events to a manageable level of GDP

202

SLIDE 204



MAPUTO

M B Q

③ **A risk transfer program that would protect Maputo against the most relevant hazards would cost ~USD 11 million per year by 2030**

USD millions

Recommended coverage scenario

- “Average” scenario ②
- 100-150-year events covered
- 2.0% GDP deductible

1 Coastal flooding and wind damage do not appear here because expected losses for 100-150-year events are less than the 2% GDP deductible

SOURCE: INGC Phase II Theme 3

203

NOTES FOR SLIDE 204:

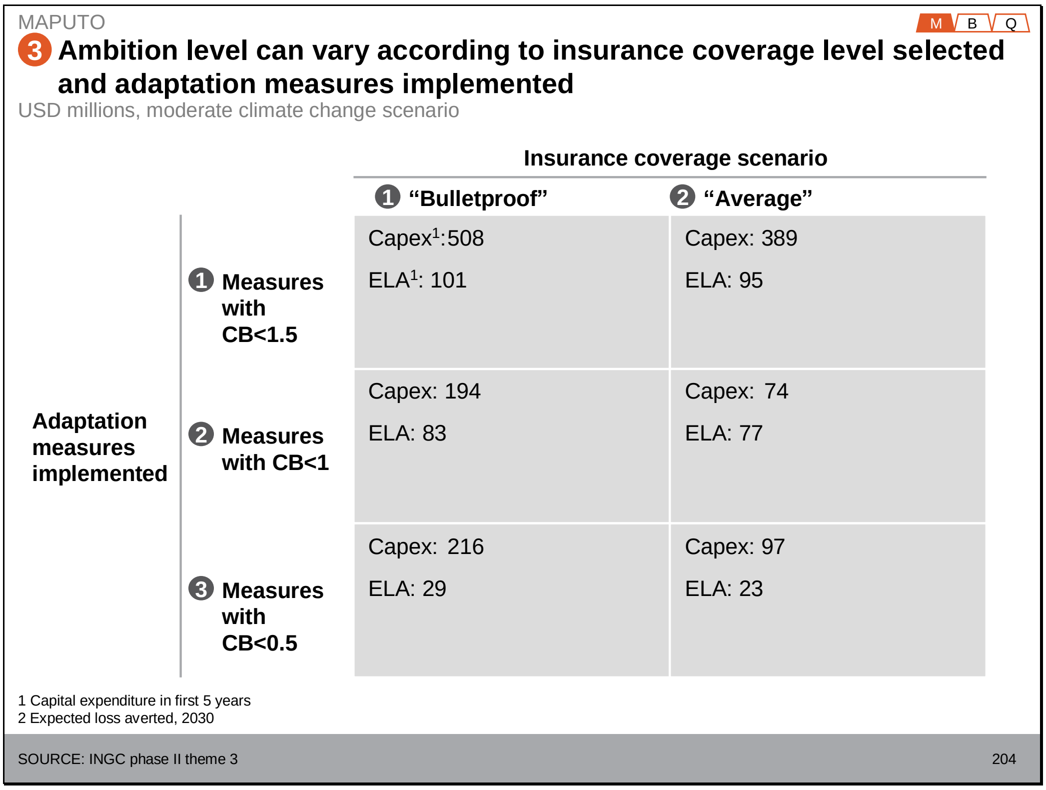
City Disaster Risk Management System and Strategy – Ambition Level

This implementation proposal builds off of discussion on methods of transferring risk for some events for which there are no cost-effective preventative measures through an insurance policy.

This uses the “Average” scenario described earlier, with a narrow range of events coverage (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks developed for each hazard type to calculate the total cost of insurance, the annual costs were identified and added to achieve the “Expected Loss to be recovered”, the risk premium multiplier was determined based on the range of coverage, and the risk premium was calculated to add to the expected loss for the total insurance cost.

SLIDE 205



MAPUTO

M B Q

③ Ambition level can vary according to insurance coverage level selected and adaptation measures implemented

USD millions, moderate climate change scenario

		Insurance coverage scenario	
		① "Bulletproof"	② "Average"
Adaptation measures implemented	① **Measures with CB<1.5**	Capex[1]:508 ELA[1]: 101	Capex: 389 ELA: 95
	② **Measures with CB<1**	Capex: 194 ELA: 83	Capex: 74 ELA: 77
	③ **Measures with CB<0.5**	Capex: 216 ELA: 29	Capex: 97 ELA: 23

1 Capital expenditure in first 5 years
2 Expected loss averted, 2030

SOURCE: INGC phase II theme 3

NOTES FOR SLIDE 205:

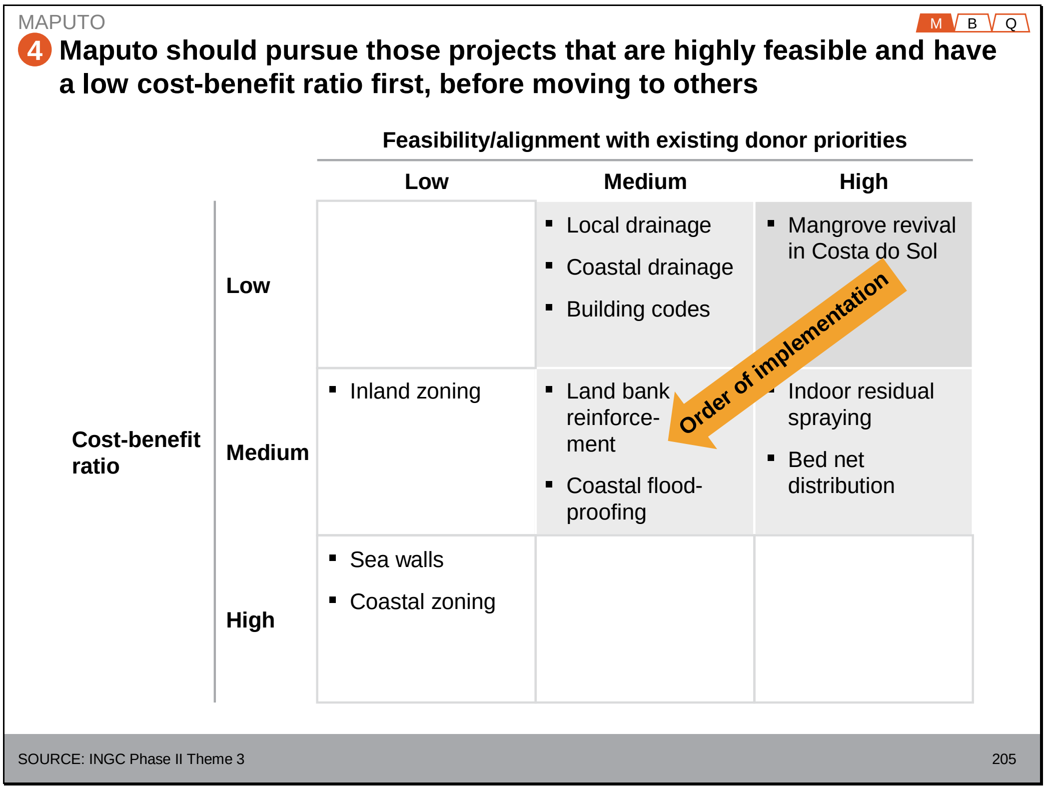
City Disaster Risk Management System and Strategy – Ambition Level

Ambition level can vary according to insurance coverage selected and adaptation measures implemented

This chart takes the portfolio view for the municipality to show various capital expenditures required for adaptation measures and insurance purchases, and the expected benefits at both:
Different levels of adaptation measure implementation by cost-benefit ratio
Different intensities of insurance coverage

Both the capital expenditure required and the expected climate change losses averted rise as one moves up the chart to higher levels of adaptation measures, and as one moves from "average" insurance coverage to "bulletproof" insurance coverage.

SLIDE 206



MAPUTO

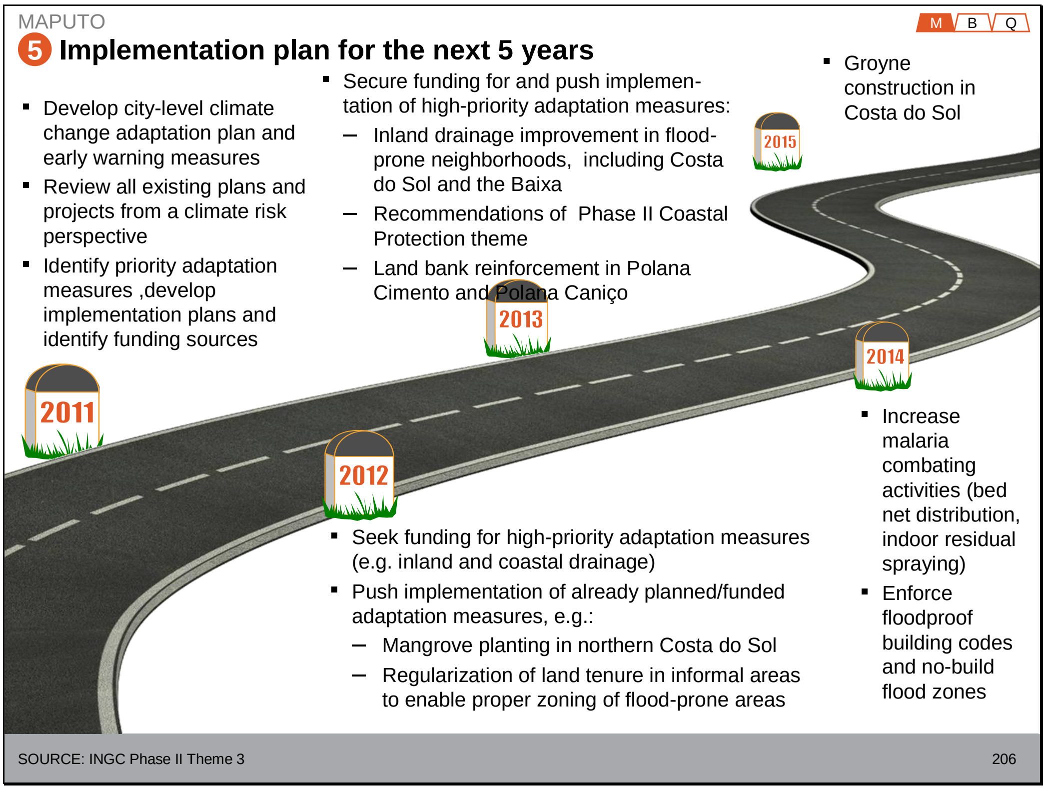
④ Maputo should pursue those projects that are highly feasible and have a low cost-benefit ratio first, before moving to others

		Feasibility/alignment with existing donor priorities		
		Low	Medium	High
Cost-benefit ratio	Low		▪ Local drainage ▪ Coastal drainage ▪ Building codes	▪ Mangrove revival in Costa do Sol
	Medium	▪ Inland zoning	▪ Land bank reinforcement ▪ Coastal flood-proofing	▪ Indoor residual spraying ▪ Bed net distribution
	High	▪ Sea walls ▪ Coastal zoning		

Order of implementation

SOURCE: INGC Phase II Theme 3

SLIDE 207



MAPUTO

⑤ Implementation plan for the next 5 years

2011

- Develop city-level climate change adaptation plan and early warning measures
- Review all existing plans and projects from a climate risk perspective
- Identify priority adaptation measures ,develop implementation plans and identify funding sources

2012

- Seek funding for high-priority adaptation measures (e.g. inland and coastal drainage)
- Push implementation of already planned/funded adaptation measures, e.g.:
  - Mangrove planting in northern Costa do Sol
  - Regularization of land tenure in informal areas to enable proper zoning of flood-prone areas

2013

- Secure funding for and push implementation of high-priority adaptation measures:
  - Inland drainage improvement in flood-prone neighborhoods, including Costa do Sol and the Baixa
  - Recommendations of Phase II Coastal Protection theme
  - Land bank reinforcement in Polana Cimento and Polana Caniço

2014

- Increase malaria combating activities (bed net distribution, indoor residual spraying)
- Enforce floodproof building codes and no-build flood zones

2015

- Groyne construction in Costa do Sol

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 207:

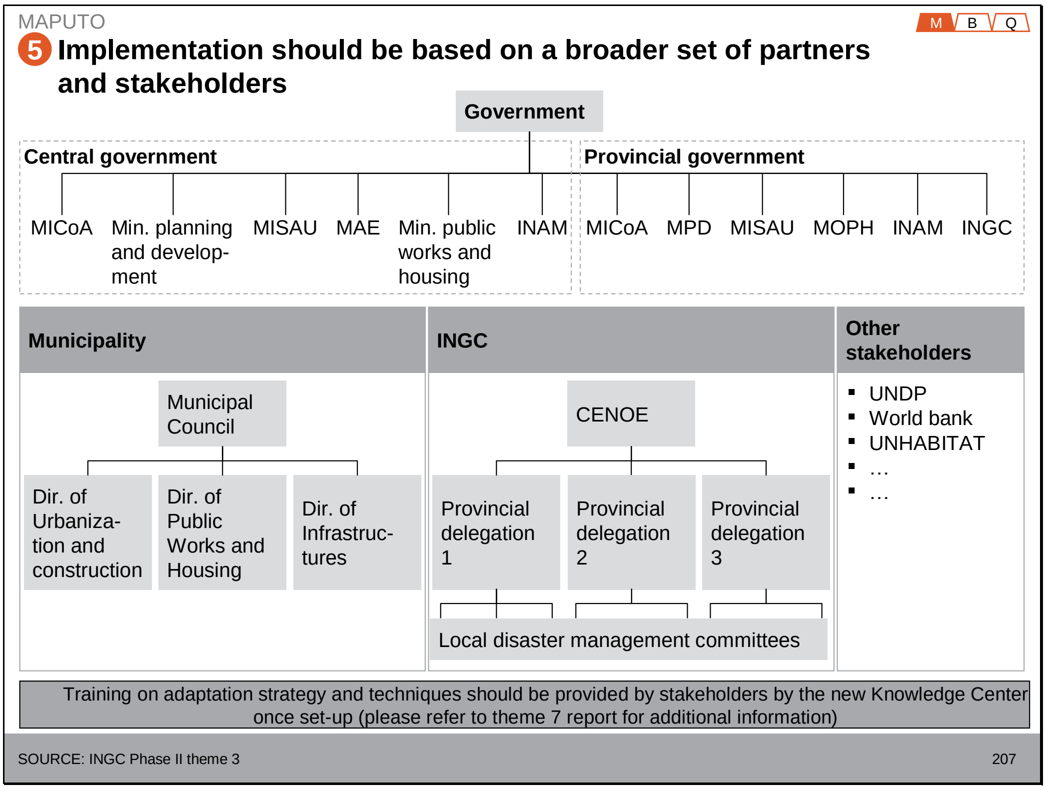
City Disaster Risk Management System and Strategy – Implementation Plan

Implementation Plan for the next 5 Years

Assuming the municipality continues with the ambition level of decreasing the costs of climate change as described in this section, this 5-year plan maps out the major priorities for each year to set the municipality on the path to halve the current % GDP impacts of climate change by 2030.

This plan includes a combination of
Strategy development and planning
Tactical planning and funding identification
Timing and geographic focus for high priority adaptation measures
Emphasis on pushing already planned / funded measures
Increased enforcement management oversight of new measures

SLIDE 208



MAPUTO

M B Q

⑤ Implementation should be based on a broader set of partners and stakeholders

Government

Central government
- MICoA
- Min. planning and development
- MISAU
- MAE
- Min. public works and housing
- INAM

Provincial government
- MICoA
- MPD
- MISAU
- MOPH
- INAM
- INGC

Municipality
- Municipal Council
  - Dir. of Urbanization and construction
  - Dir. of Public Works and Housing
  - Dir. of Infrastructures

INGC
- CENOE
  - Provincial delegation 1
  - Provincial delegation 2
  - Provincial delegation 3
    - Local disaster management committees

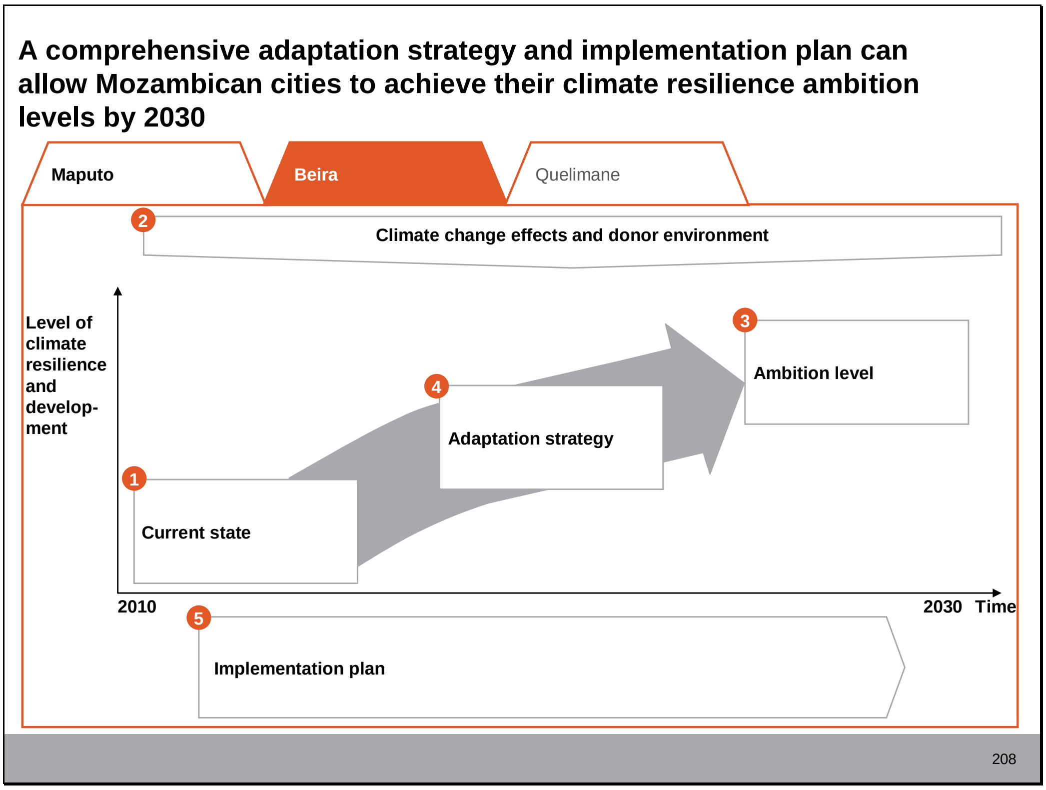
Other stakeholders
- UNDP
- World bank
- UNHABITAT
- …
- …

Training on adaptation strategy and techniques should be provided by stakeholders by the new Knowledge Center once set-up (please refer to theme 7 report for additional information)

SOURCE: INGC Phase II theme 3

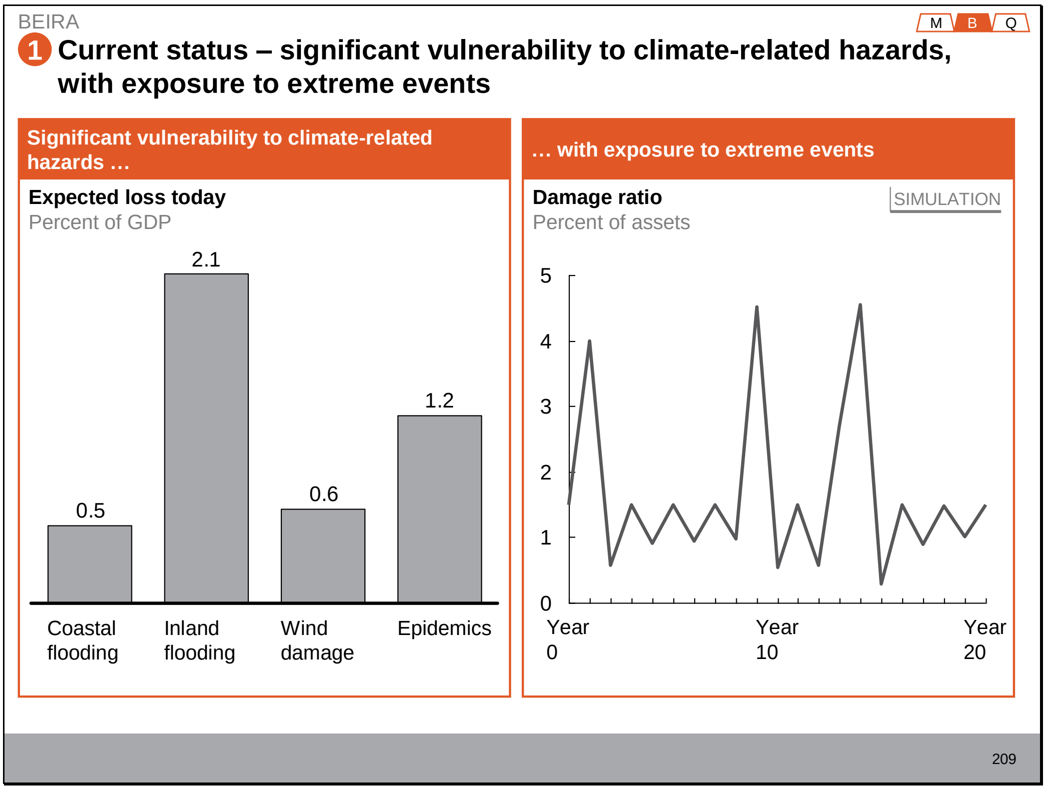
207

SLIDE 209



A comprehensive adaptation strategy and implementation plan can allow Mozambican cities to achieve their climate resilience ambition levels by 2030

SLIDE 210



BEIRA

① Current status – significant vulnerability to climate-related hazards, with exposure to extreme events

Significant vulnerability to climate-related hazards …

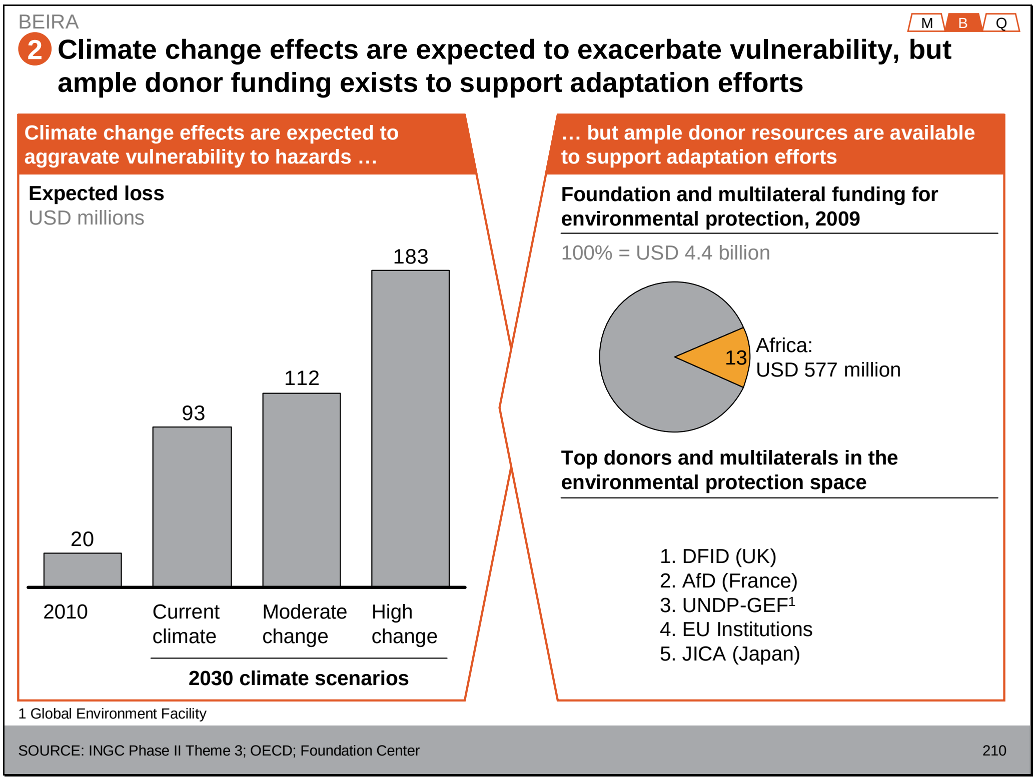
Expected loss today
Percent of GDP

… with exposure to extreme events

Damage ratio
Percent of assets

SIMULATION

SLIDE 211



BEIRA

② Climate change effects are expected to exacerbate vulnerability, but ample donor funding exists to support adaptation efforts

Climate change effects are expected to aggravate vulnerability to hazards …

Expected loss
USD millions

… but ample donor resources are available to support adaptation efforts

Foundation and multilateral funding for environmental protection, 2009
100% = USD 4.4 billion

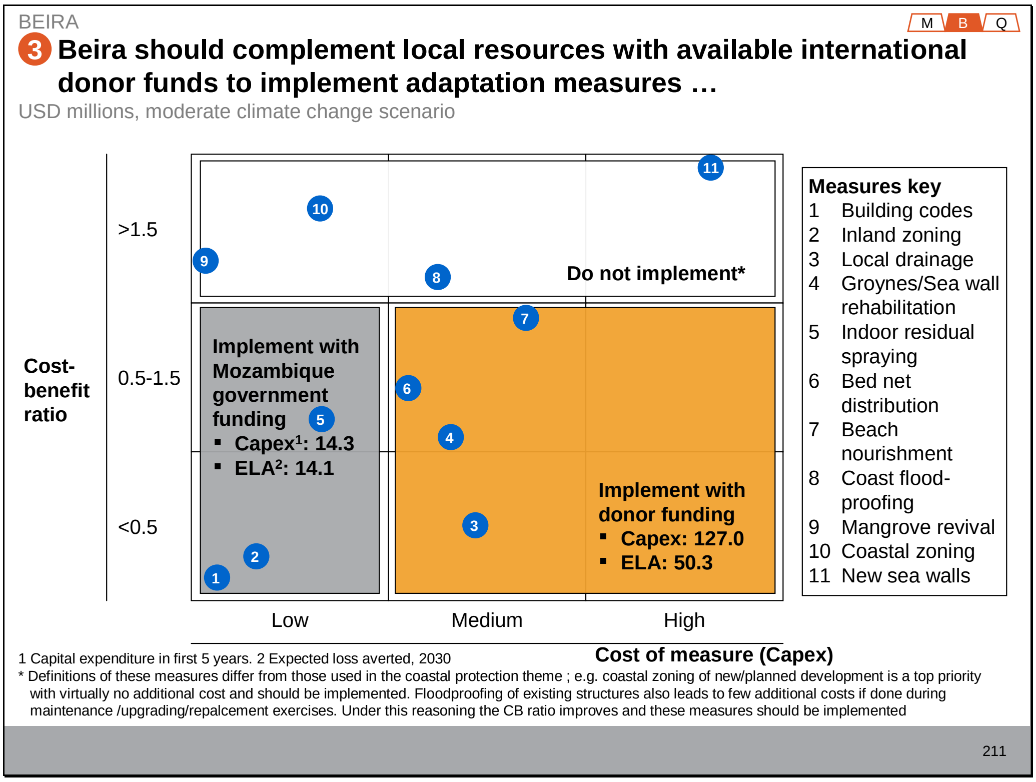
Top donors and multilaterals in the environmental protection space

1. DFID (UK)
2. AfD (France)
3. UNDP-GEF[1]
4. EU Institutions
5. JICA (Japan)

[1] Global Environment Facility

SOURCE: INGC Phase II Theme 3; OECD; Foundation Center

SLIDE 212



BEIRA

③ Beira should complement local resources with available international donor funds to implement adaptation measures …

USD millions, moderate climate change scenario

Do not implement*

Implement with Mozambique government funding
- **Capex[1]: 14.3**
- **ELA[2]: 14.1**

Implement with donor funding
- **Capex: 127.0**
- **ELA: 50.3**

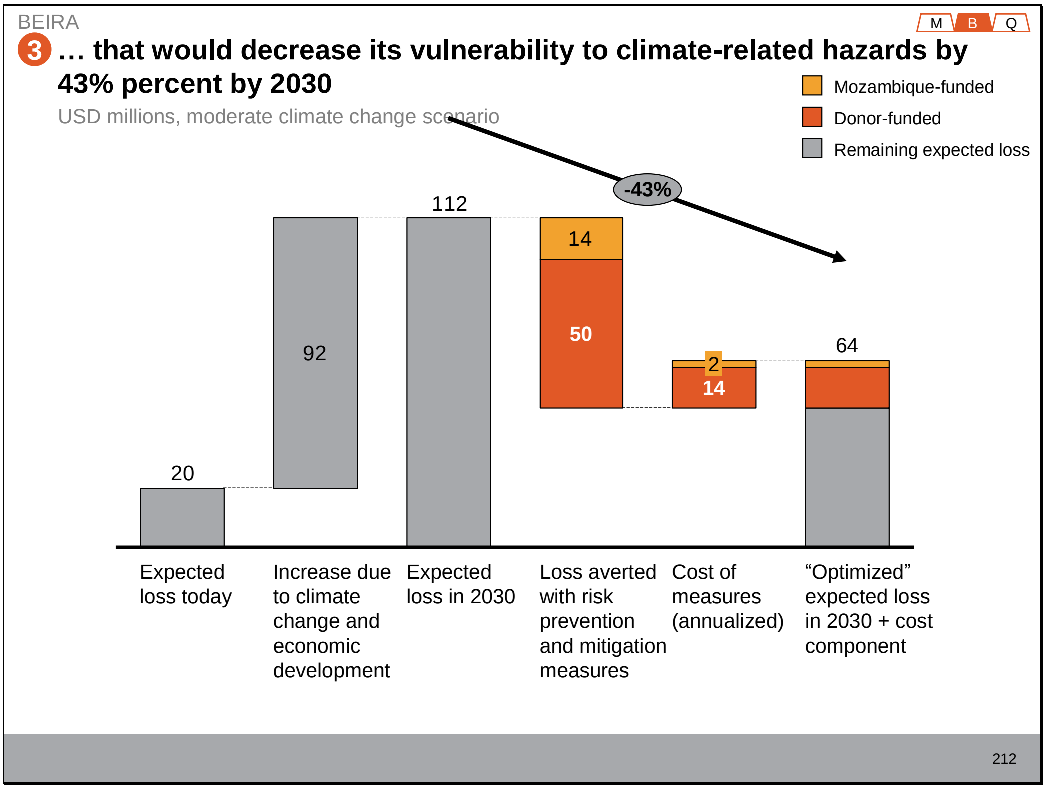
Measures key

1	Building codes
2	Inland zoning
3	Local drainage
4	Groynes/Sea wall rehabilitation
5	Indoor residual spraying
6	Bed net distribution
7	Beach nourishment
8	Coast flood-proofing
9	Mangrove revival
10	Coastal zoning
11	New sea walls

[1] Capital expenditure in first 5 years. [2] Expected loss averted, 2030

* Definitions of these measures differ from those used in the coastal protection theme ; e.g. coastal zoning of new/planned development is a top priority with virtually no additional cost and should be implemented. Floodproofing of existing structures also leads to few additional costs if done during maintenance /upgrading/repalcement exercises. Under this reasoning the CB ratio improves and these measures should be implemented

SLIDE 213



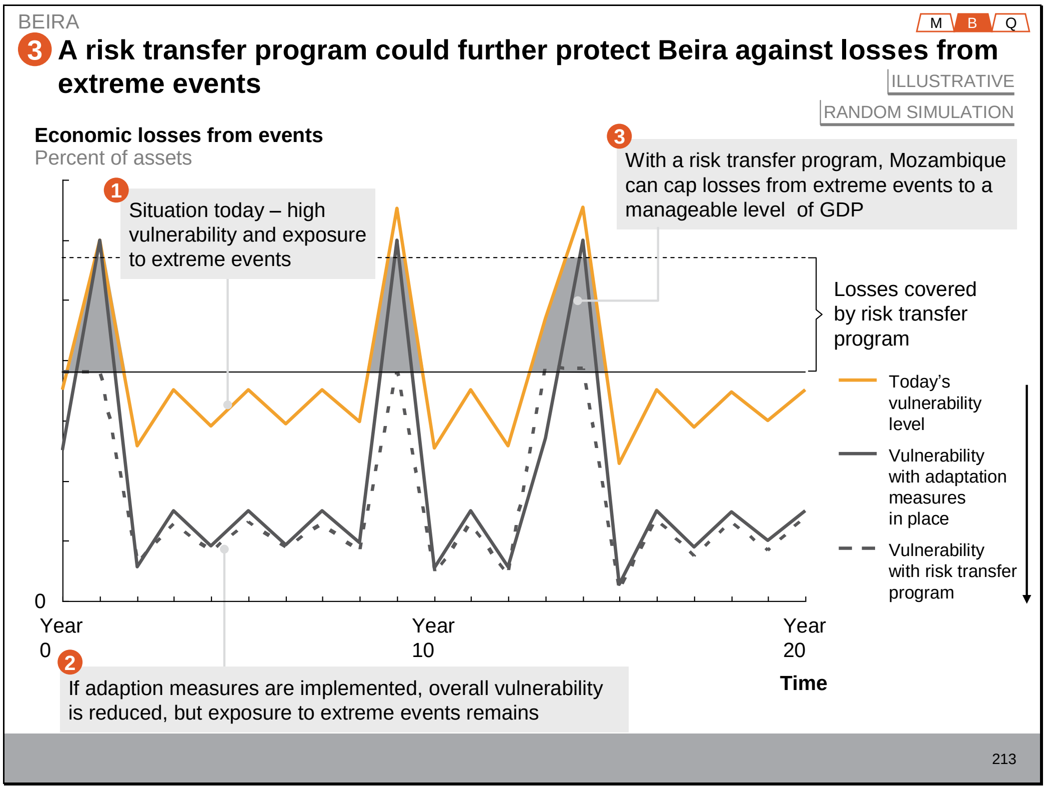
BEIRA

M B Q

③ … that would decrease its vulnerability to climate-related hazards by 43% percent by 2030

USD millions, moderate climate change scenario

SLIDE 214



BEIRA

M B Q

③ A risk transfer program could further protect Beira against losses from extreme events

ILLUSTRATIVE

RANDOM SIMULATION

Economic losses from events

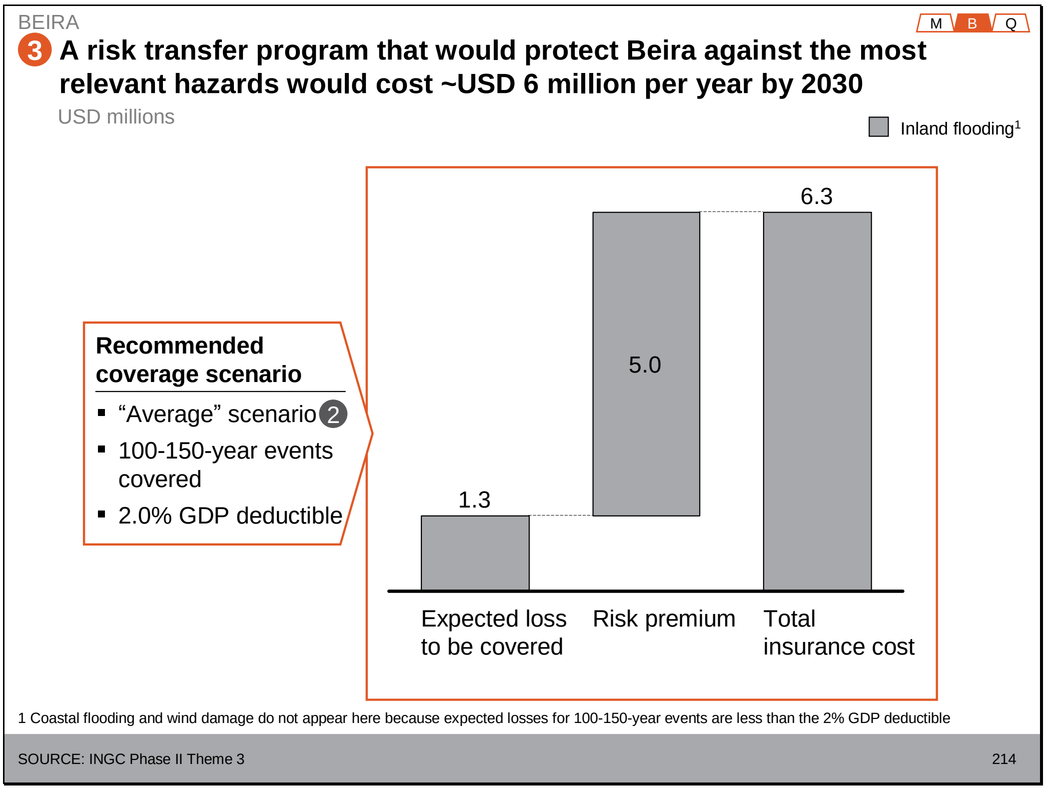
Percent of assets

① Situation today – high vulnerability and exposure to extreme events

② If adaption measures are implemented, overall vulnerability is reduced, but exposure to extreme events remains

③ With a risk transfer program, Mozambique can cap losses from extreme events to a manageable level of GDP

SLIDE 215



BEIRA

M B Q

③ A risk transfer program that would protect Beira against the most relevant hazards would cost ~USD 6 million per year by 2030

USD millions

▨ Inland flooding[1]

Recommended coverage scenario

- "Average" scenario ②
- 100-150-year events covered
- 2.0% GDP deductible

1 Coastal flooding and wind damage do not appear here because expected losses for 100-150-year events are less than the 2% GDP deductible

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 215:

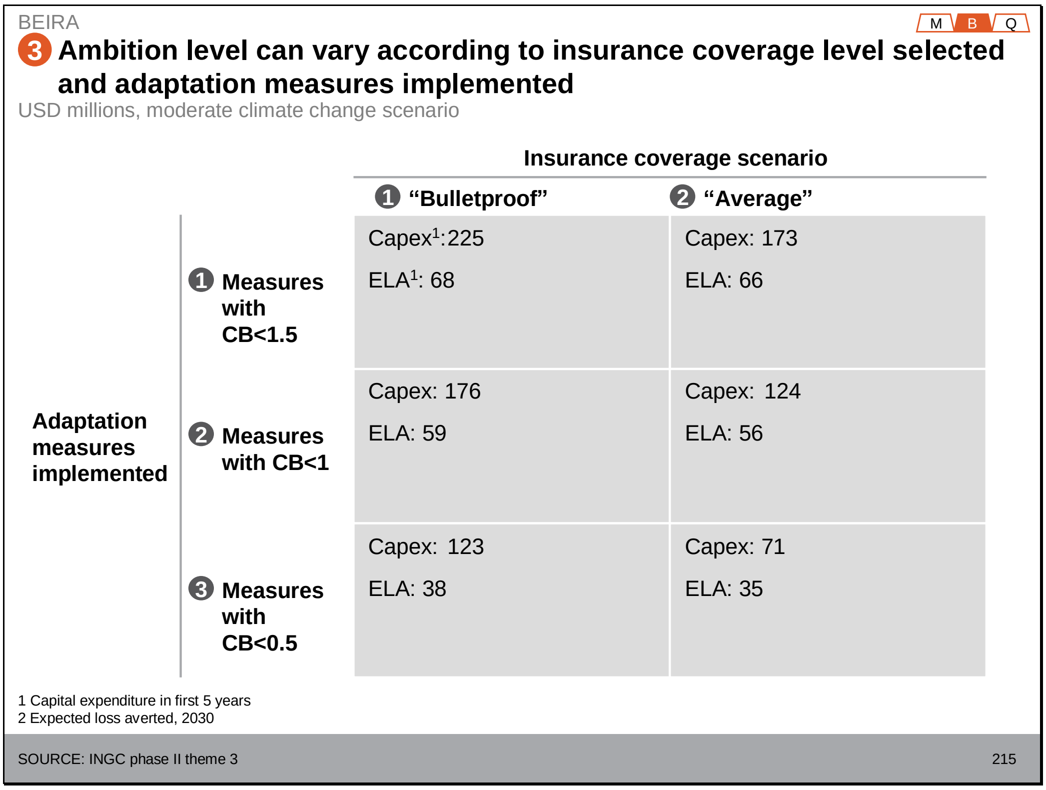
City Disaster Risk Management System and Strategy – Ambition Level

This implementation proposal builds off of discussion on methods of transferring risk for some events for which there are no cost-effective preventative measures through an insurance policy.

This uses the "Average" scenario described earlier, with a narrow range of events coverage (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks developed for each hazard type to calculate the total cost of insurance, the annual costs were identified and added to achieve the "Expected Loss to be recovered", the risk premium multiplier was determined based on the range of coverage, and the risk premium was calculated to add to the expected loss for the total insurance cost.

SLIDE 216



BEIRA

M B Q

③ Ambition level can vary according to insurance coverage level selected and adaptation measures implemented

USD millions, moderate climate change scenario

		Insurance coverage scenario	
		① **"Bulletproof"**	② **"Average"**
Adaptation measures implemented	① **Measures with CB<1.5**	Capex^1:225 ELA^1: 68	Capex: 173 ELA: 66
	② **Measures with CB<1**	Capex: 176 ELA: 59	Capex: 124 ELA: 56
	③ **Measures with CB<0.5**	Capex: 123 ELA: 38	Capex: 71 ELA: 35

1 Capital expenditure in first 5 years
2 Expected loss averted, 2030

SOURCE: INGC phase II theme 3

NOTES FOR SLIDE 216:

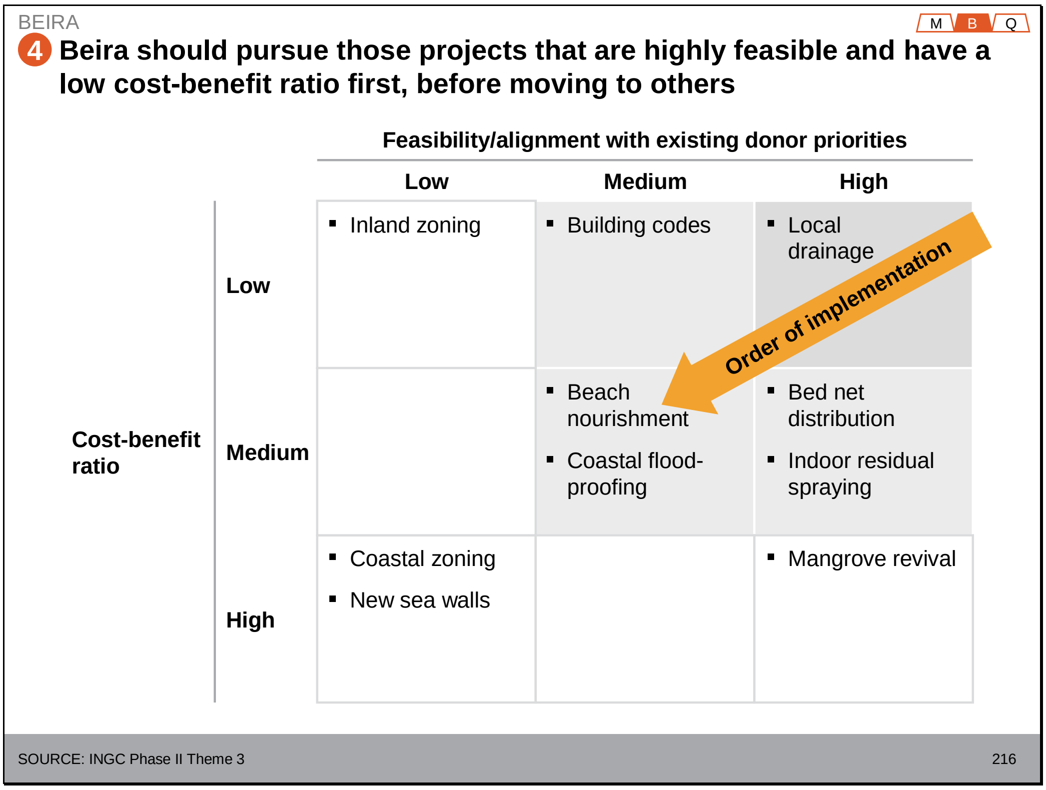
City Disaster Risk Management System and Strategy – Ambition Level

Ambition level can vary according to insurance coverage selected and adaptation measures implemented

This chart takes the portfolio view for the municipality to show various capital expenditures required for adaptation measures and insurance purchases, and the expected benefits at both:
Different levels of adaptation measure implementation by cost-benefit ratio
Different intensities of insurance coverage

Both the capital expenditure required and the expected climate change losses averted rise as one moves up the chart to higher levels of adaptation measures, and as one moves from "average" insurance coverage to "bulletproof" insurance coverage.

SLIDE 217



BEIRA

M B Q

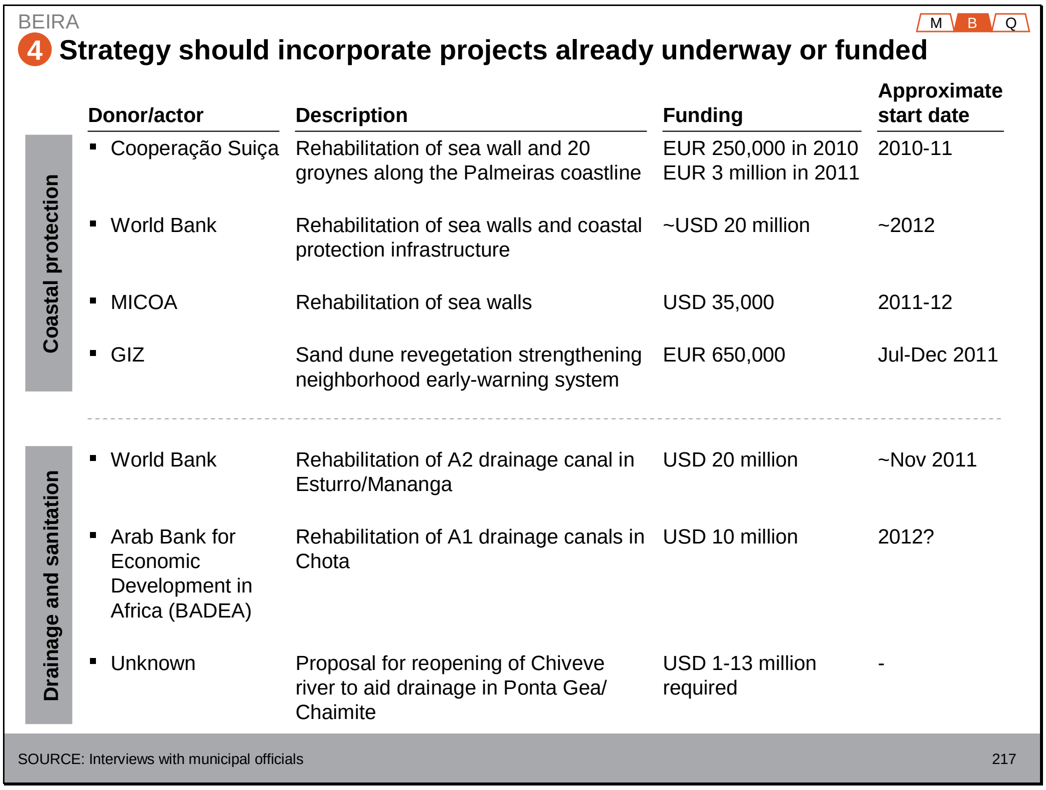
4 Beira should pursue those projects that are highly feasible and have a low cost-benefit ratio first, before moving to others

Feasibility/alignment with existing donor priorities

Cost-benefit ratio	**Low**	**Medium**	**High**
Low	▪ Inland zoning	▪ Building codes	▪ Local drainage
Medium		▪ Beach nourishment ▪ Coastal flood-proofing	▪ Bed net distribution ▪ Indoor residual spraying
High	▪ Coastal zoning ▪ New sea walls		▪ Mangrove revival

SOURCE: INGC Phase II Theme 3

SLIDE 218



BEIRA

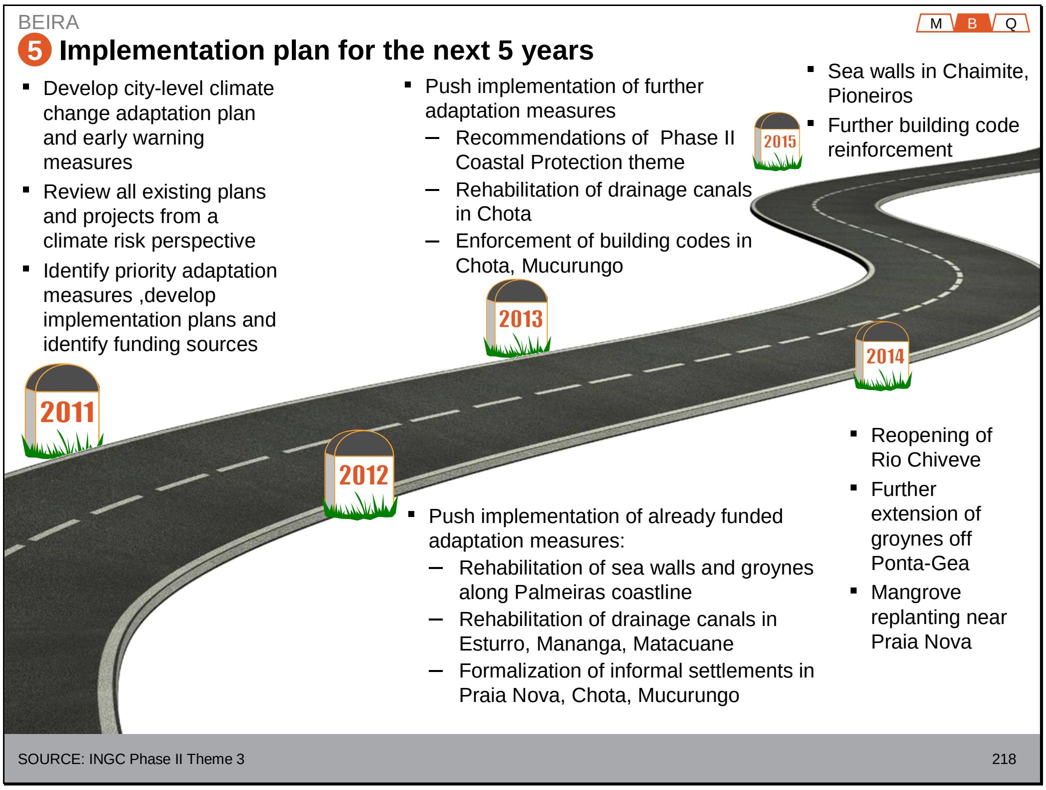
M B Q

4 Strategy should incorporate projects already underway or funded

	Donor/actor	Description	Funding	Approximate start date
Coastal protection	▪ Cooperação Suiça	Rehabilitation of sea wall and 20 groynes along the Palmeiras coastline	EUR 250,000 in 2010 EUR 3 million in 2011	2010-11
	▪ World Bank	Rehabilitation of sea walls and coastal protection infrastructure	~USD 20 million	~2012
	▪ MICOA	Rehabilitation of sea walls	USD 35,000	2011-12
	▪ GIZ	Sand dune revegetation strengthening neighborhood early-warning system	EUR 650,000	Jul-Dec 2011
Drainage and sanitation	▪ World Bank	Rehabilitation of A2 drainage canal in Esturro/Mananga	USD 20 million	~Nov 2011
	▪ Arab Bank for Economic Development in Africa (BADEA)	Rehabilitation of A1 drainage canals in Chota	USD 10 million	2012?
	▪ Unknown	Proposal for reopening of Chiveve river to aid drainage in Ponta Gea/ Chaimite	USD 1-13 million required	-

SOURCE: Interviews with municipal officials

SLIDE 219



BEIRA

M B Q

5 Implementation plan for the next 5 years

2011

- Develop city-level climate change adaptation plan and early warning measures
- Review all existing plans and projects from a climate risk perspective
- Identify priority adaptation measures ,develop implementation plans and identify funding sources

2012

- Push implementation of already funded adaptation measures:
  - Rehabilitation of sea walls and groynes along Palmeiras coastline
  - Rehabilitation of drainage canals in Esturro, Mananga, Matacuane
  - Formalization of informal settlements in Praia Nova, Chota, Mucurungo

2013

- Push implementation of further adaptation measures
  - Recommendations of Phase II Coastal Protection theme
  - Rehabilitation of drainage canals in Chota
  - Enforcement of building codes in Chota, Mucurungo

2014

- Reopening of Rio Chiveve
- Further extension of groynes off Ponta-Gea
- Mangrove replanting near Praia Nova

2015

- Sea walls in Chaimite, Pioneiros
- Further building code reinforcement

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 219:

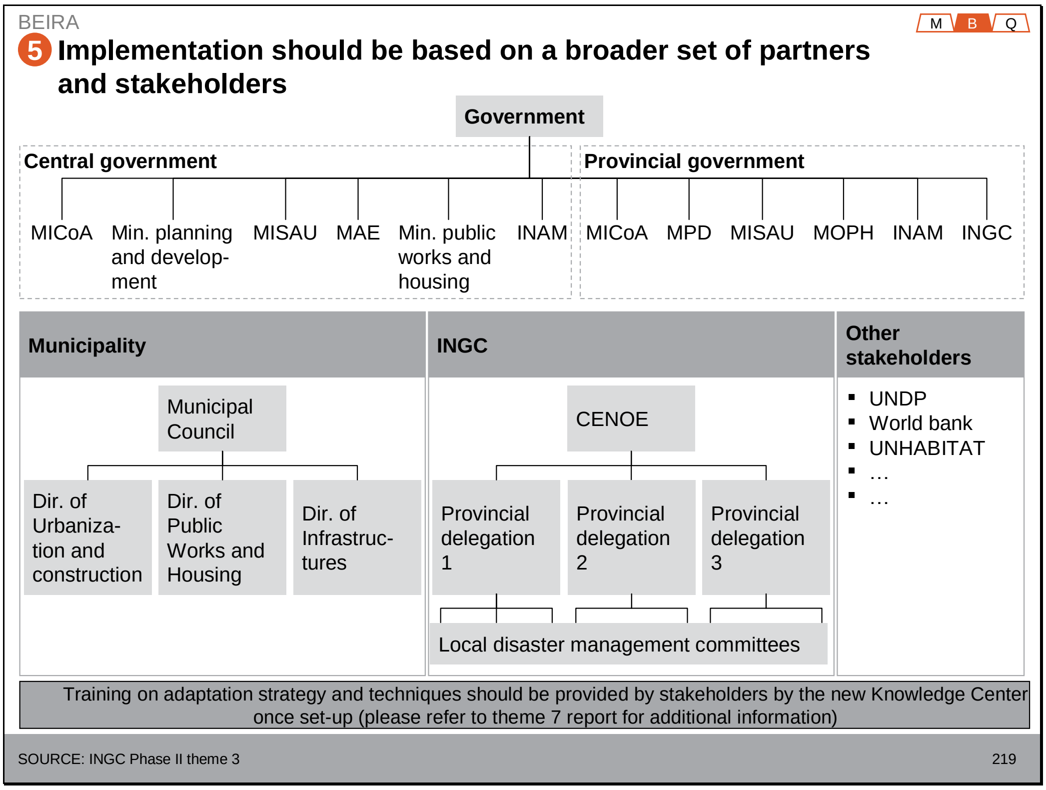
City Disaster Risk Management System and Strategy – Implementation Plan

Implementation Plan for the next 5 Years

Assuming the municipality continues with the ambition level of decreasing the costs of climate change as described in this section, this 5-year plan maps out the major priorities for each year to set the municipality on the path to halve the current % GDP impacts of climate change by 2030.

This plan includes a combination of
Strategy development and planning
Tactical planning and funding identification
Timing and geographic focus for high priority adaptation measures
Emphasis on pushing already planned / funded measures
Increased enforcement management oversight of new measures
Groundwork for measure implementation, e.g. formalization of settlements

SLIDE 220



BEIRA

M B Q

⑤ Implementation should be based on a broader set of partners and stakeholders

Government

Central government
- MICoA
- Min. planning and development
- MISAU
- MAE
- Min. public works and housing
- INAM

Provincial government
- MICoA
- MPD
- MISAU
- MOPH
- INAM
- INGC

Municipality

Municipal Council
- Dir. of Urbanization and construction
- Dir. of Public Works and Housing
- Dir. of Infrastructures

INGC

CENOE
- Provincial delegation 1
- Provincial delegation 2
- Provincial delegation 3

Local disaster management committees

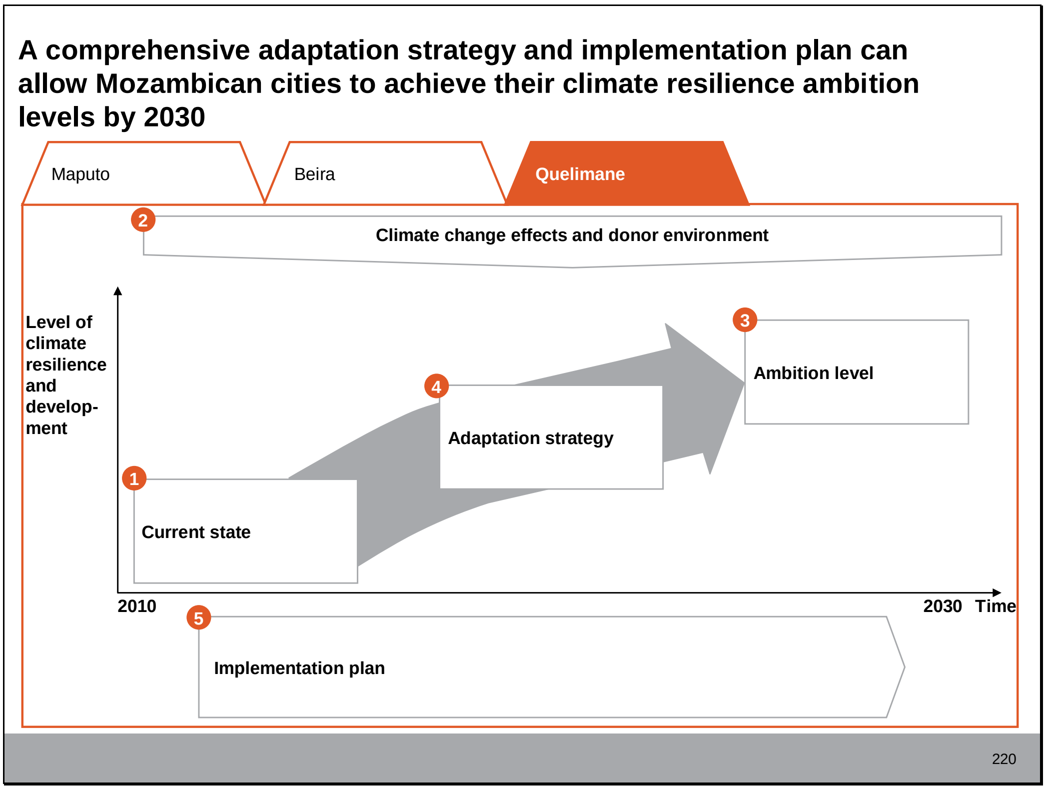
Other stakeholders
- UNDP
- World bank
- UNHABITAT
- …
- …

Training on adaptation strategy and techniques should be provided by stakeholders by the new Knowledge Center once set-up (please refer to theme 7 report for additional information)

SOURCE: INGC Phase II theme 3

219

SLIDE 221



A comprehensive adaptation strategy and implementation plan can allow Mozambican cities to achieve their climate resilience ambition levels by 2030

Maputo | Beira | **Quelimane**

② **Climate change effects and donor environment**

Level of climate resilience and develop-ment

① **Current state**

④ **Adaptation strategy**

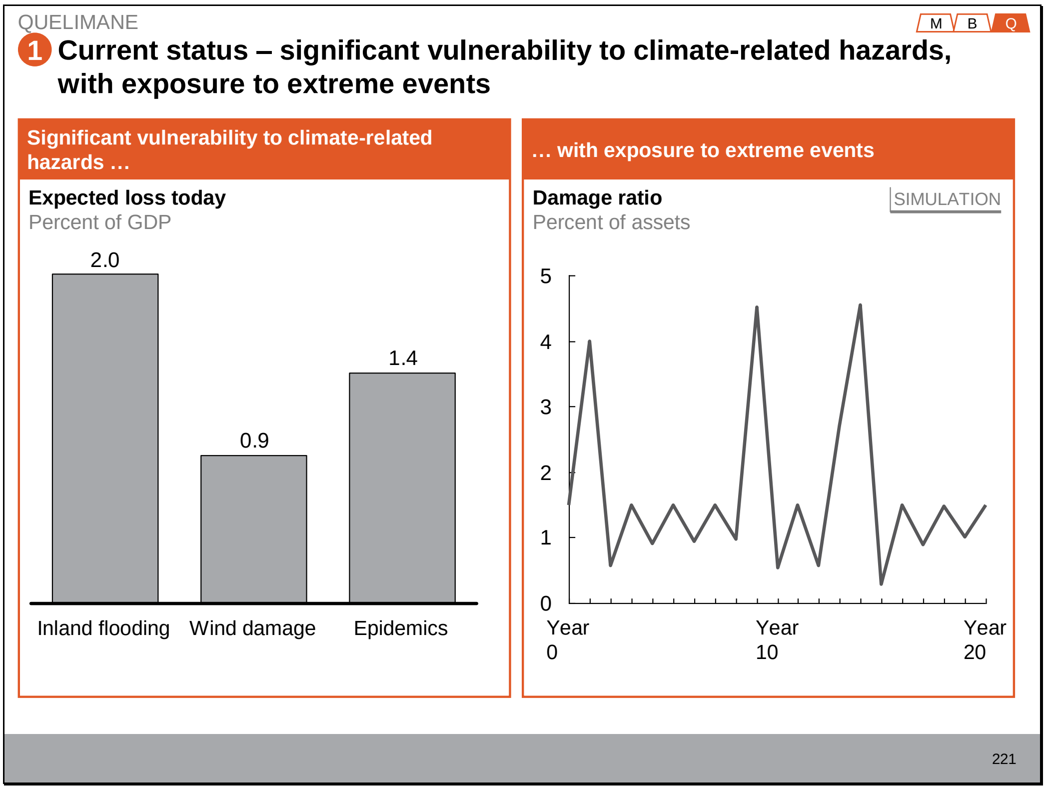
③ **Ambition level**

2010 **2030 Time**

⑤ **Implementation plan**

220

SLIDE 222



QUELIMANE

① Current status – significant vulnerability to climate-related hazards, with exposure to extreme events

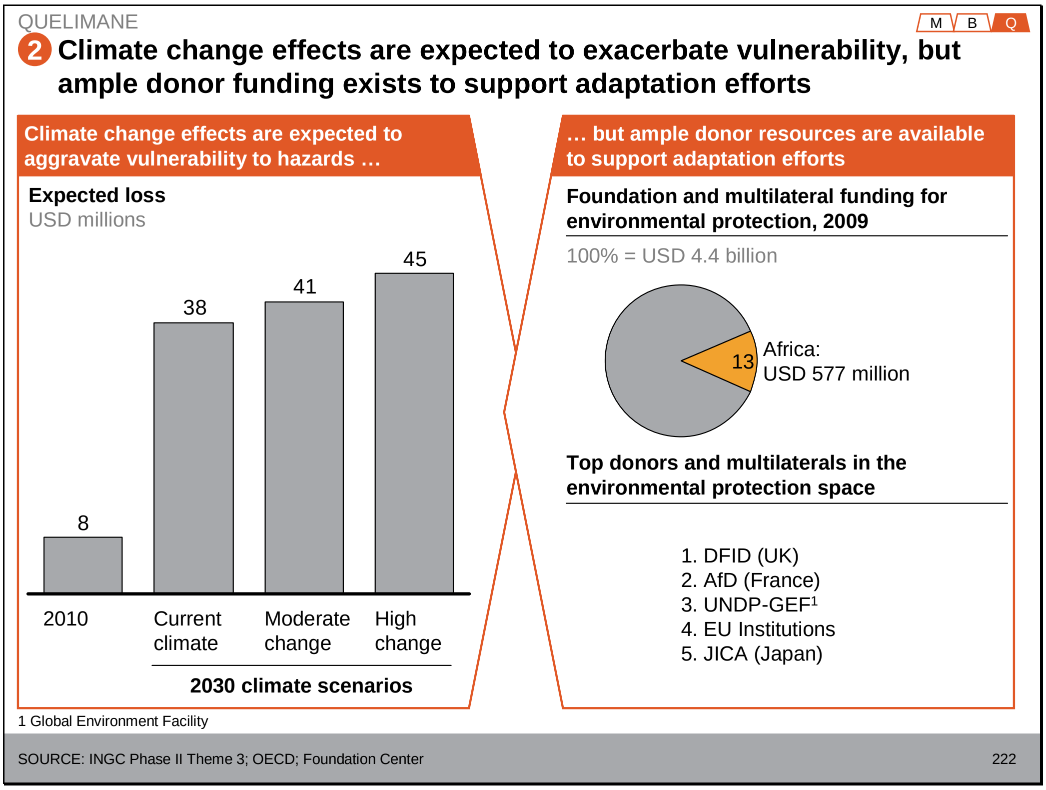
Significant vulnerability to climate-related hazards …

Expected loss today
Percent of GDP

… with exposure to extreme events

Damage ratio
Percent of assets

SLIDE 223



QUELIMANE

② Climate change effects are expected to exacerbate vulnerability, but ample donor funding exists to support adaptation efforts

Climate change effects are expected to aggravate vulnerability to hazards …

Expected loss
USD millions

… but ample donor resources are available to support adaptation efforts

Foundation and multilateral funding for environmental protection, 2009

100% = USD 4.4 billion

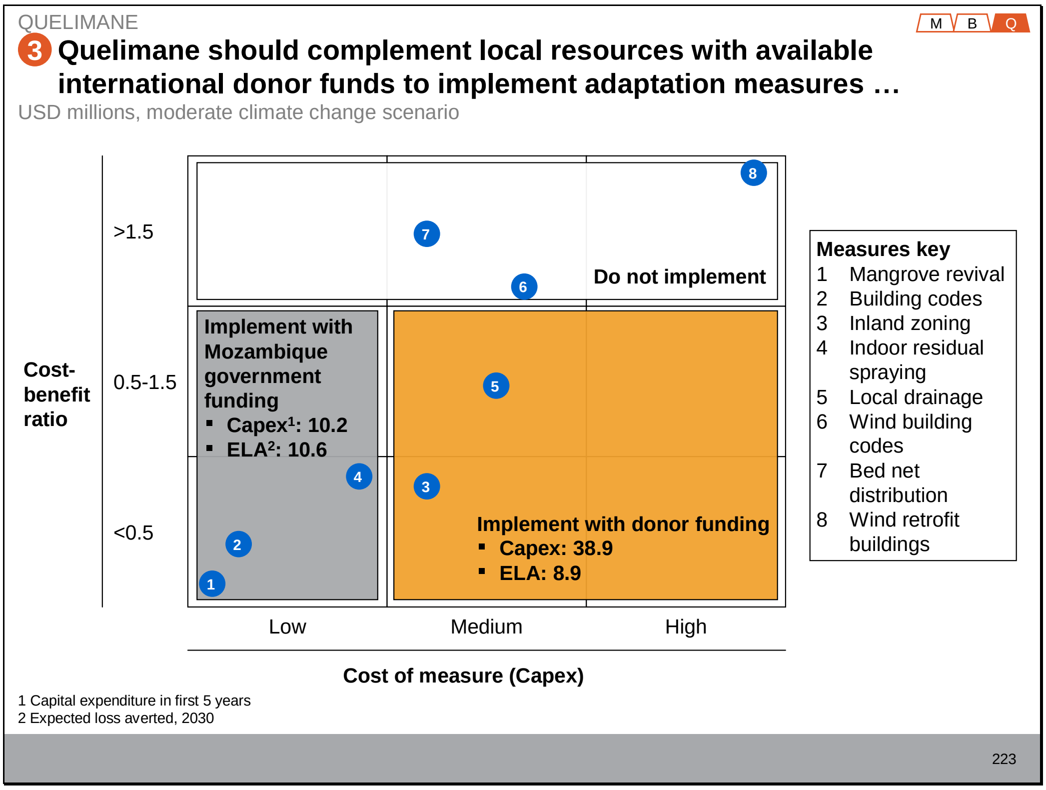
Top donors and multilaterals in the environmental protection space

1. DFID (UK)
2. AfD (France)
3. UNDP-GEF[1]
4. EU Institutions
5. JICA (Japan)

1 Global Environment Facility

SOURCE: INGC Phase II Theme 3; OECD; Foundation Center

SLIDE 224



QUELIMANE

M B Q

③ Quelimane should complement local resources with available international donor funds to implement adaptation measures …

USD millions, moderate climate change scenario

Do not implement

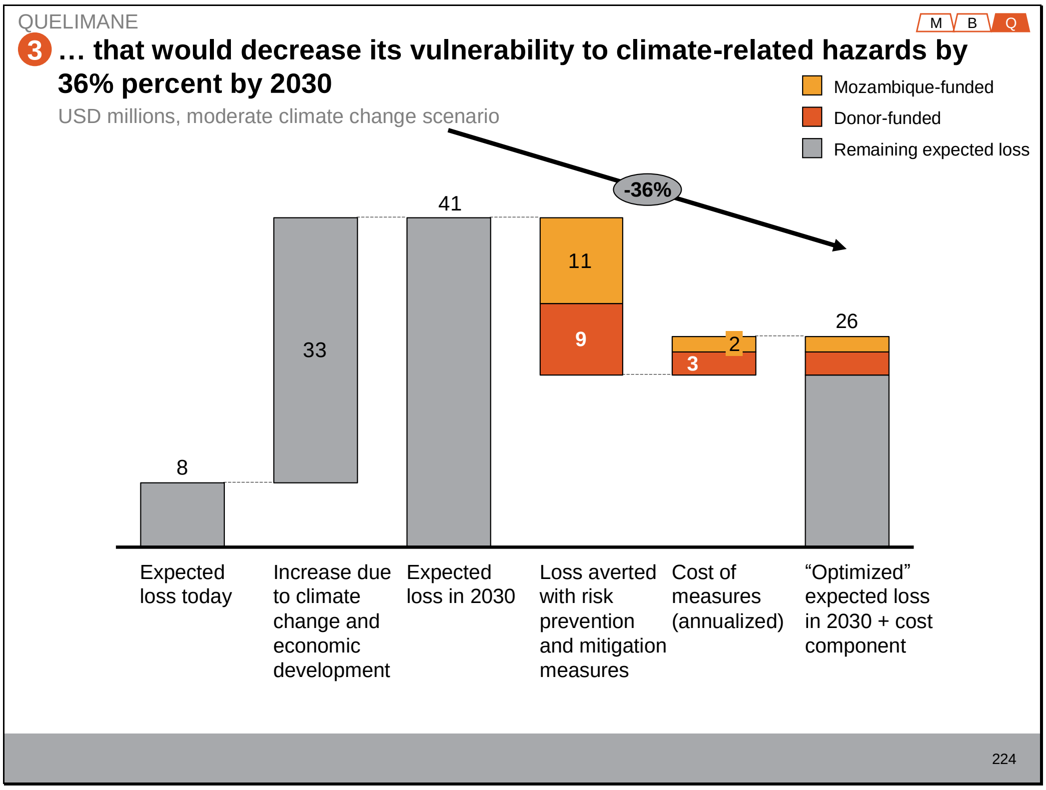
Implement with Mozambique government funding
- **Capex¹: 10.2**
- **ELA²: 10.6**

Implement with donor funding
- **Capex: 38.9**
- **ELA: 8.9**

Measures key
1 Mangrove revival
2 Building codes
3 Inland zoning
4 Indoor residual spraying
5 Local drainage
6 Wind building codes
7 Bed net distribution
8 Wind retrofit buildings

1 Capital expenditure in first 5 years
2 Expected loss averted, 2030

SLIDE 225



QUELIMANE

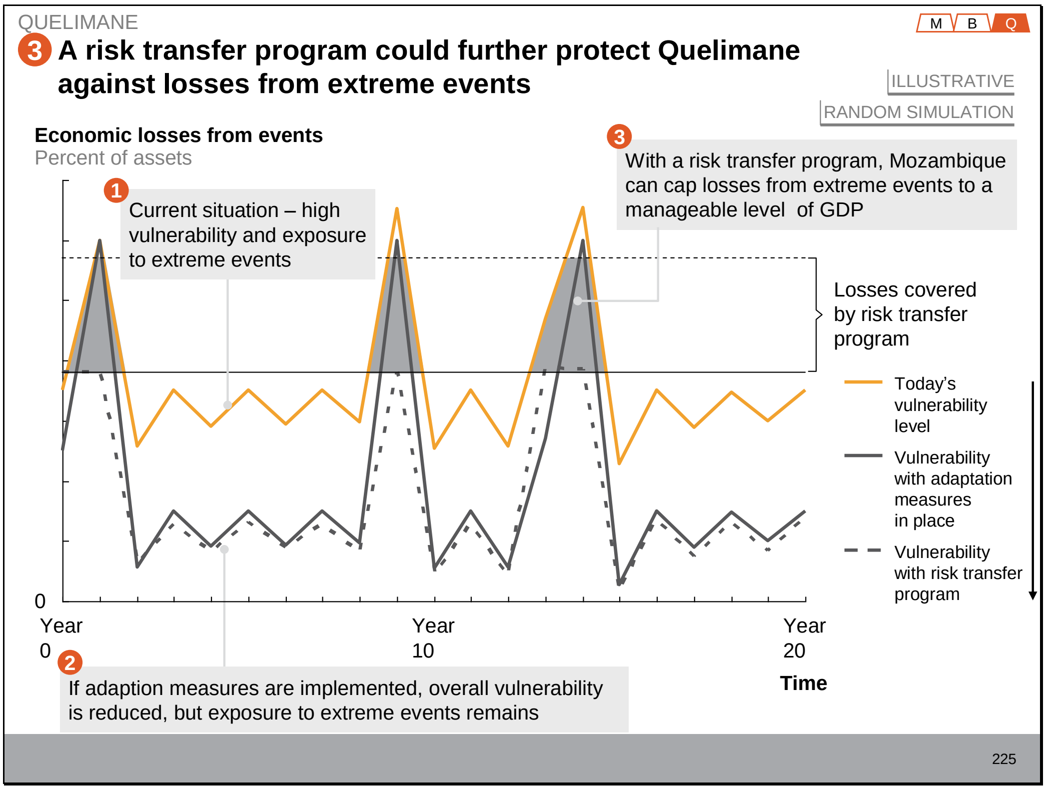
M B Q

③ … that would decrease its vulnerability to climate-related hazards by 36% percent by 2030

USD millions, moderate climate change scenario

🟧 Mozambique-funded
🟥 Donor-funded
⬜ Remaining expected loss

SLIDE 226



QUELIMANE

③ A risk transfer program could further protect Quelimane against losses from extreme events

ILLUSTRATIVE

RANDOM SIMULATION

Economic losses from events
Percent of assets

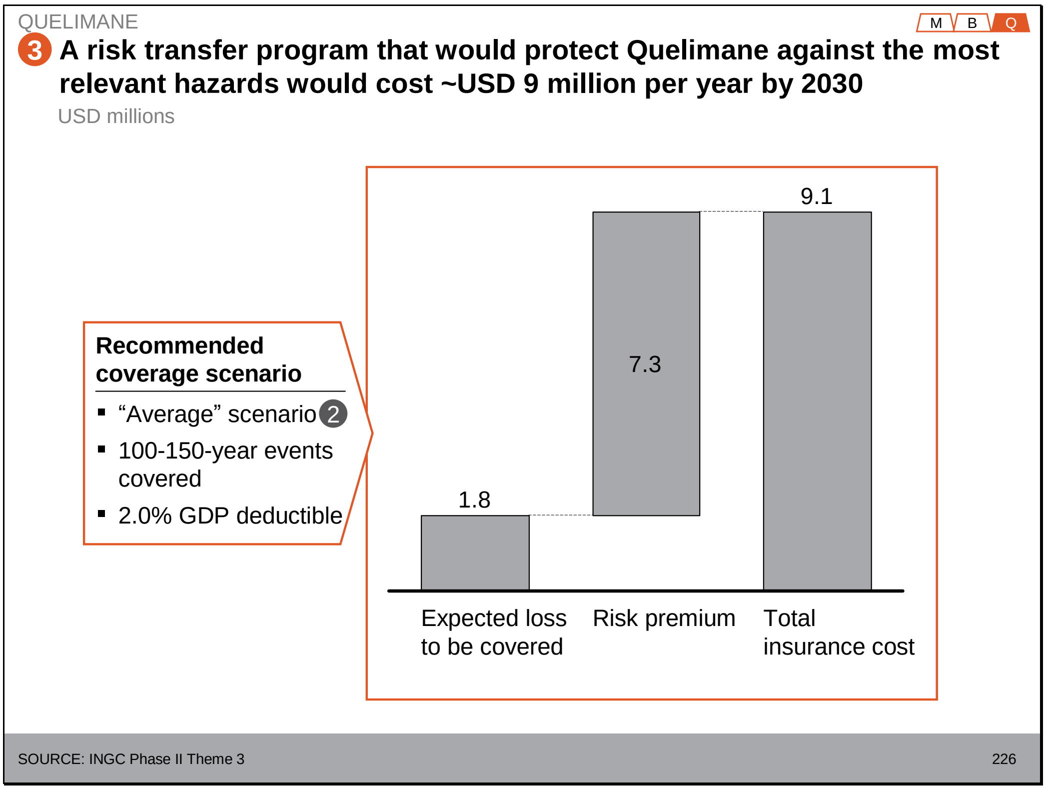
① Current situation – high vulnerability and exposure to extreme events

② If adaption measures are implemented, overall vulnerability is reduced, but exposure to extreme events remains

③ With a risk transfer program, Mozambique can cap losses from extreme events to a manageable level of GDP

- Today's vulnerability level
- Vulnerability with adaptation measures in place
- Vulnerability with risk transfer program

SLIDE 227



QUELIMANE

③ A risk transfer program that would protect Quelimane against the most relevant hazards would cost ~USD 9 million per year by 2030

USD millions

Recommended coverage scenario
- "Average" scenario ②
- 100-150-year events covered
- 2.0% GDP deductible

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 227:

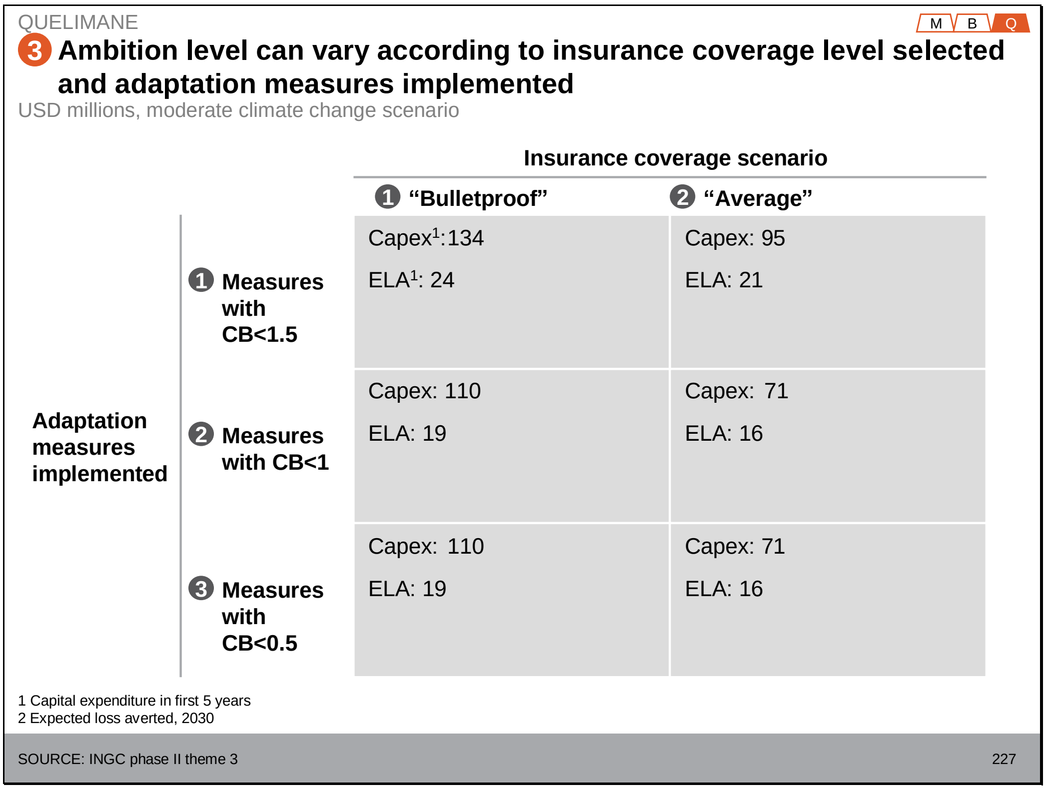
City Disaster Risk Management System and Strategy – Ambition Level

This implementation proposal builds off of discussion on methods of transferring risk for some events for which there are no cost-effective preventative measures through an insurance policy.

This uses the "Average" scenario described earlier, with a narrow range of events coverage (100-150 year events only) and a higher deductible - 2.0% of GDP.

Using the playbooks developed for each hazard type to calculate the total cost of insurance, the annual costs were identified and added to achieve the "Expected Loss to be recovered", the risk premium multiplier was determined based on the range of coverage, and the risk premium was calculated to add to the expected loss for the total insurance cost.

SLIDE 228



QUELIMANE

M B Q

③ Ambition level can vary according to insurance coverage level selected and adaptation measures implemented

USD millions, moderate climate change scenario

		Insurance coverage scenario	
		① "Bulletproof"	**② "Average"**
Adaptation measures implemented	**① Measures with CB<1.5**	Capex[1]:134 ELA[1]: 24	Capex: 95 ELA: 21
	② Measures with CB<1	Capex: 110 ELA: 19	Capex: 71 ELA: 16
	③ Measures with CB<0.5	Capex: 110 ELA: 19	Capex: 71 ELA: 16

1 Capital expenditure in first 5 years
2 Expected loss averted, 2030

SOURCE: INGC phase II theme 3

227

NOTES FOR SLIDE 228:

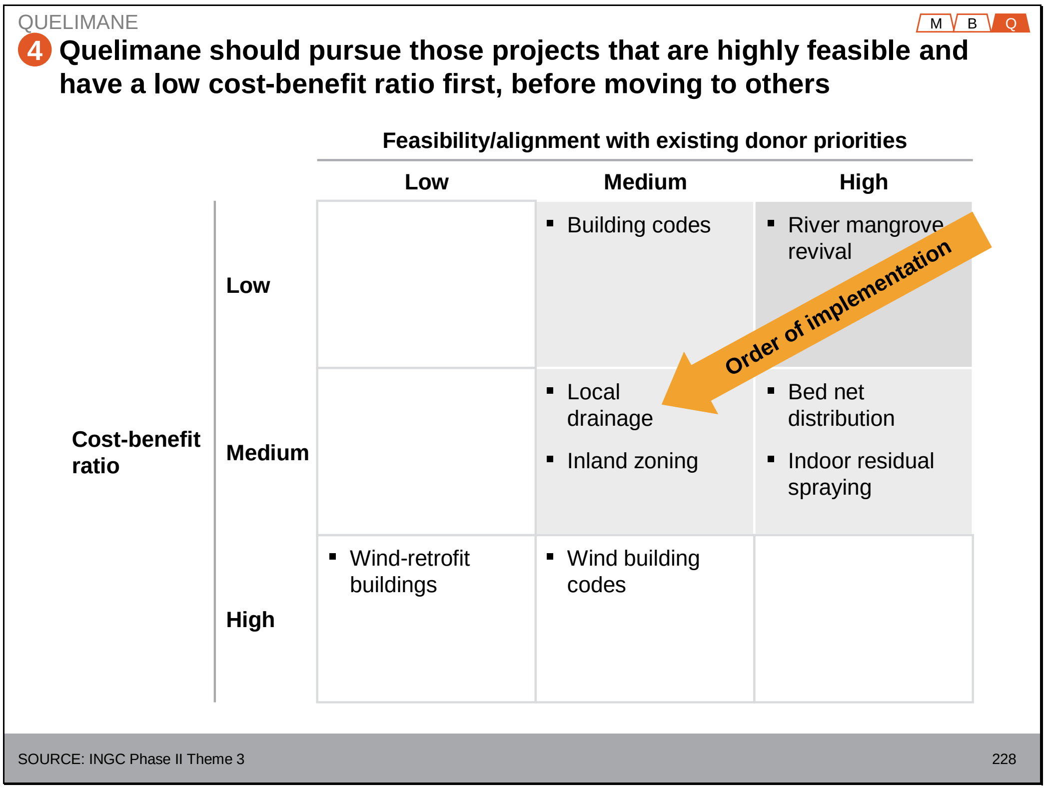
City Disaster Risk Management System and Strategy – Ambition Level

Ambition level can vary according to insurance coverage selected and adaptation measures implemented

This chart takes the portfolio view for the municipality to show various capital expenditures required for adaptation measures and insurance purchases, and the expected benefits at both:
Different levels of adaptation measure implementation by cost-benefit ratio
Different intensities of insurance coverage

Both the capital expenditure required and the expected climate change losses averted rise as one moves up the chart to higher levels of adaptation measures, and as one moves from "average" insurance coverage to "bulletproof" insurance coverage.

SLIDE 229



QUELIMANE

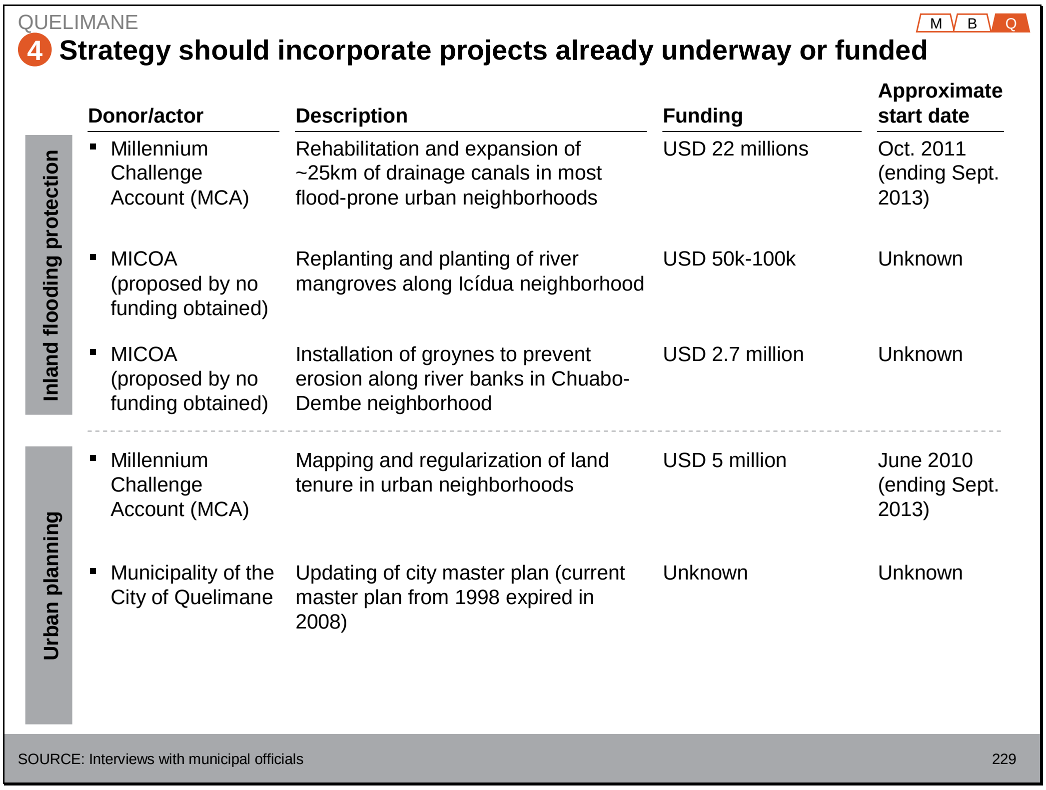
M B Q

④ Quelimane should pursue those projects that are highly feasible and have a low cost-benefit ratio first, before moving to others

		Feasibility/alignment with existing donor priorities		
		Low	**Medium**	**High**
Cost-benefit ratio	**Low**		▪ Building codes	▪ River mangrove revival
	Medium		▪ Local drainage ▪ Inland zoning	▪ Bed net distribution ▪ Indoor residual spraying
	High	▪ Wind-retrofit buildings	▪ Wind building codes	

SOURCE: INGC Phase II Theme 3

SLIDE 230



QUELIMANE

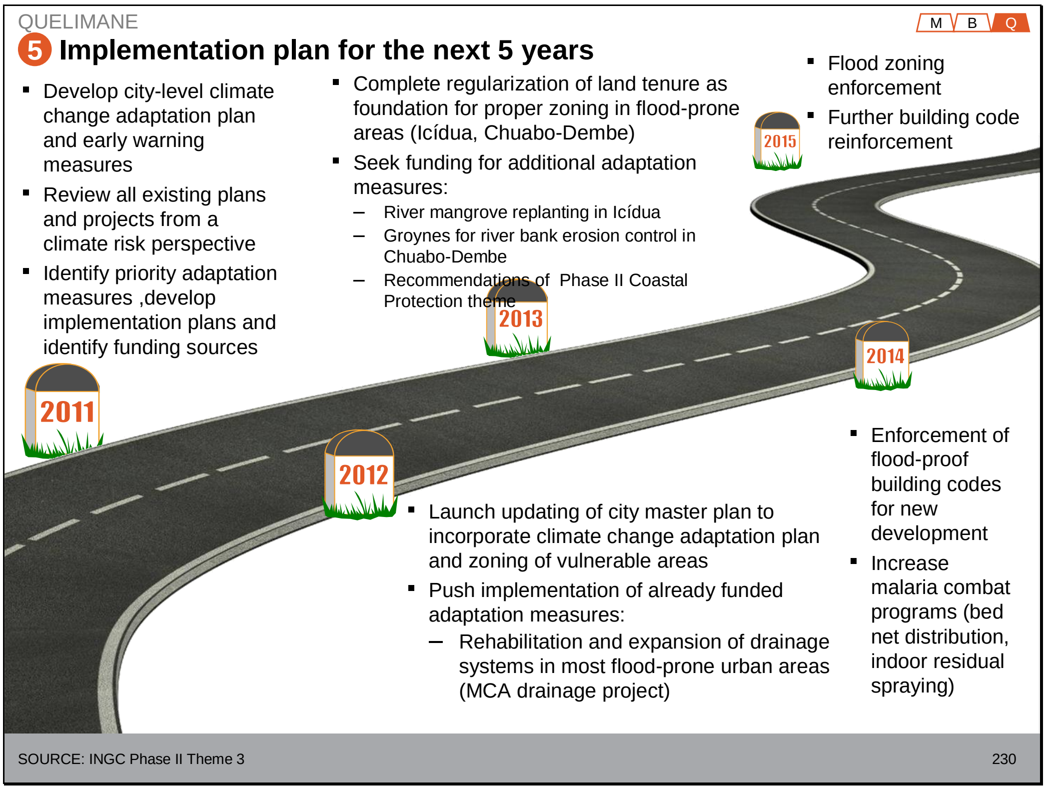
M B Q

④ Strategy should incorporate projects already underway or funded

	Donor/actor	Description	Funding	Approximate start date
Inland flooding protection	▪ Millennium Challenge Account (MCA)	Rehabilitation and expansion of ~25km of drainage canals in most flood-prone urban neighborhoods	USD 22 millions	Oct. 2011 (ending Sept. 2013)
	▪ MICOA (proposed by no funding obtained)	Replanting and planting of river mangroves along Icídua neighborhood	USD 50k-100k	Unknown
	▪ MICOA (proposed by no funding obtained)	Installation of groynes to prevent erosion along river banks in Chuabo-Dembe neighborhood	USD 2.7 million	Unknown
Urban planning	▪ Millennium Challenge Account (MCA)	Mapping and regularization of land tenure in urban neighborhoods	USD 5 million	June 2010 (ending Sept. 2013)
	▪ Municipality of the City of Quelimane	Updating of city master plan (current master plan from 1998 expired in 2008)	Unknown	Unknown

SOURCE: Interviews with municipal officials

SLIDE 231



QUELIMANE

M B Q

⑤ Implementation plan for the next 5 years

- Develop city-level climate change adaptation plan and early warning measures
- Review all existing plans and projects from a climate risk perspective
- Identify priority adaptation measures ,develop implementation plans and identify funding sources

- Launch updating of city master plan to incorporate climate change adaptation plan and zoning of vulnerable areas
- Push implementation of already funded adaptation measures:
  - Rehabilitation and expansion of drainage systems in most flood-prone urban areas (MCA drainage project)

- Complete regularization of land tenure as foundation for proper zoning in flood-prone areas (Icídua, Chuabo-Dembe)
- Seek funding for additional adaptation measures:
  - River mangrove replanting in Icídua
  - Groynes for river bank erosion control in Chuabo-Dembe
  - Recommendations of Phase II Coastal Protection theme

- Enforcement of flood-proof building codes for new development
- Increase malaria combat programs (bed net distribution, indoor residual spraying)

- Flood zoning enforcement
- Further building code reinforcement

SOURCE: INGC Phase II Theme 3

NOTES FOR SLIDE 231:

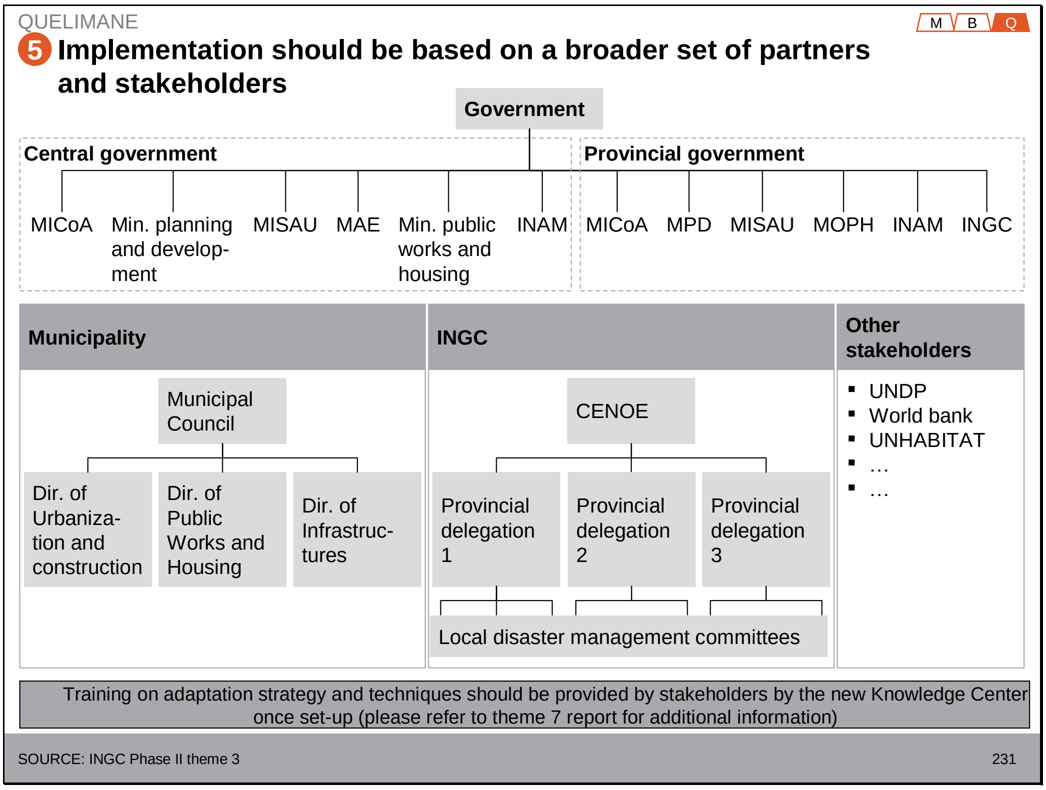
City Disaster Risk Management System and Strategy – Implementation Plan

Implementation Plan for the next 5 Years

Assuming the municipality continues with the ambition level of decreasing the costs of climate change as described in this section, this 5-year plan maps out the major priorities for each year to set the municipality on the path to halve the current % GDP impacts of climate change by 2030.

This plan includes a combination of
Strategy development and planning
Tactical planning and funding identification
Timing and geographic focus for high priority adaptation measures
Emphasis on pushing already planned / funded measures
Increased enforcement management oversight of new measures
Groundwork for measure implementation, e.g. formalization of settlements

SLIDE 232



QUELIMANE

M B Q

⑤ Implementation should be based on a broader set of partners and stakeholders

Government

Central government

MICoA
Min. planning and develop-ment
MISAU
MAE
Min. public works and housing
INAM

Provincial government

MICoA
MPD
MISAU
MOPH
INAM
INGC

Municipality

Municipal Council
Dir. of Urbaniza-tion and construction
Dir. of Public Works and Housing
Dir. of Infrastruc-tures

INGC

CENOE
Provincial delegation 1
Provincial delegation 2
Provincial delegation 3
Local disaster management committees

Other stakeholders

- UNDP
- World bank
- UNHABITAT
- …
- …

Training on adaptation strategy and techniques should be provided by stakeholders by the new Knowledge Center once set-up (please refer to theme 7 report for additional information)

SOURCE: INGC Phase II theme 3

231

SLIDE 233

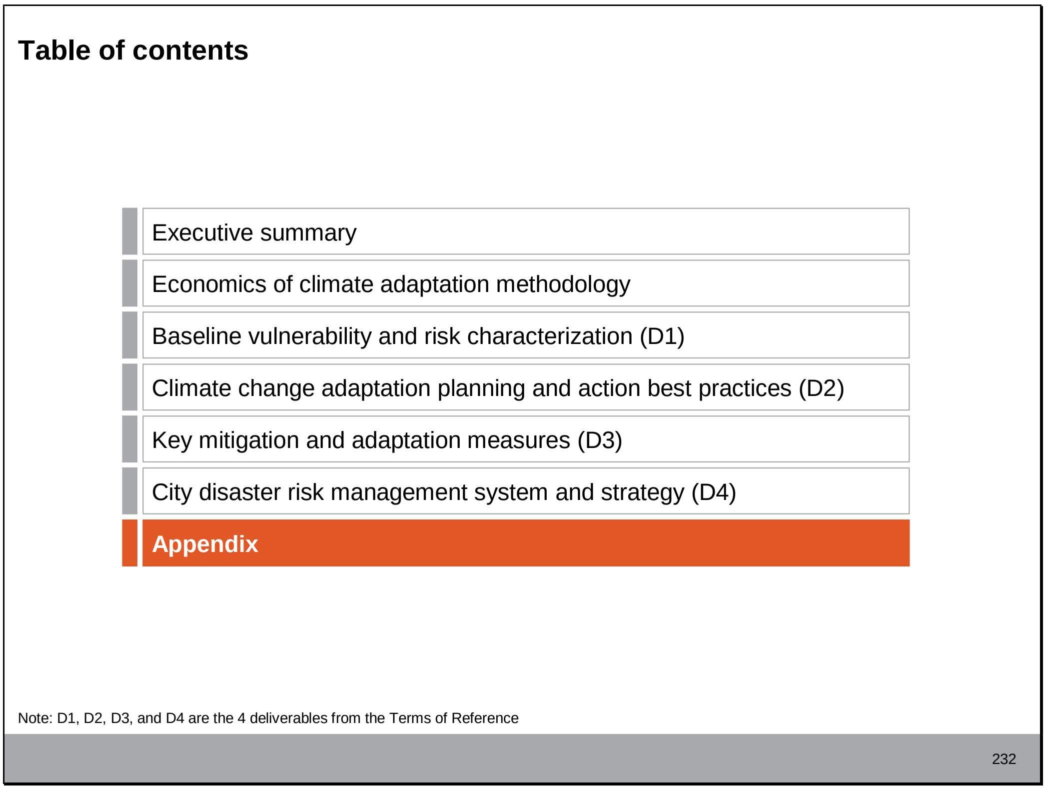
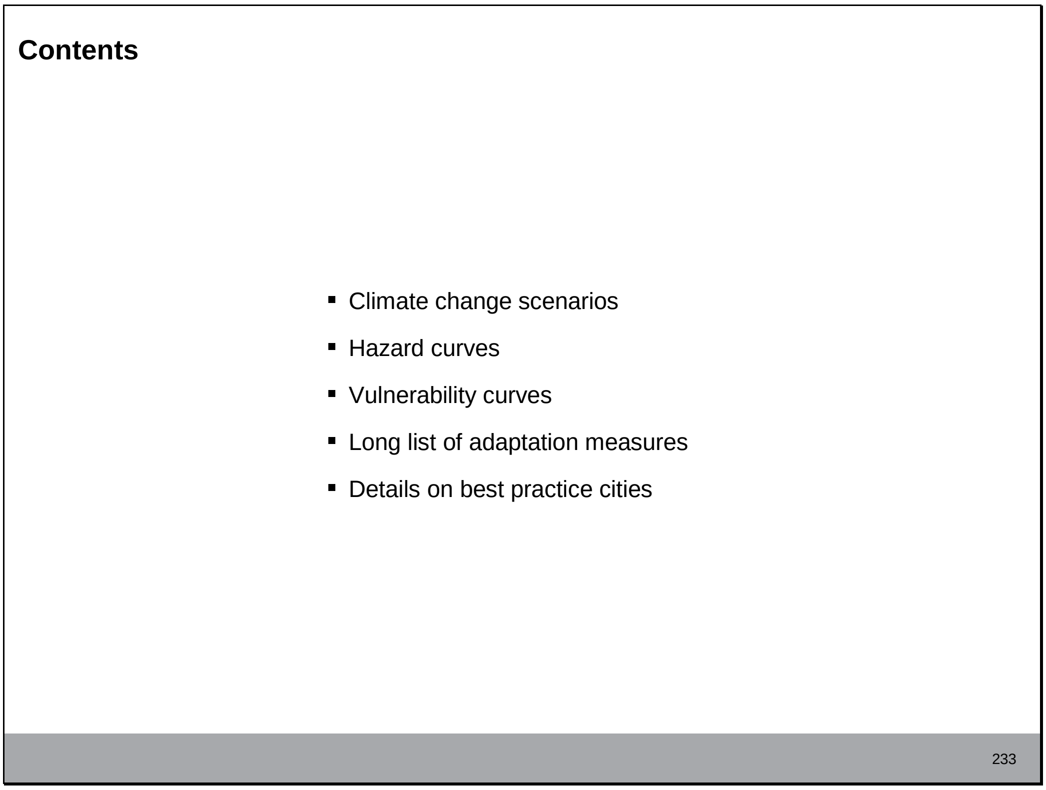


Table of contents

Note: D1, D2, D3, and D4 are the 4 deliverables from the Terms of Reference

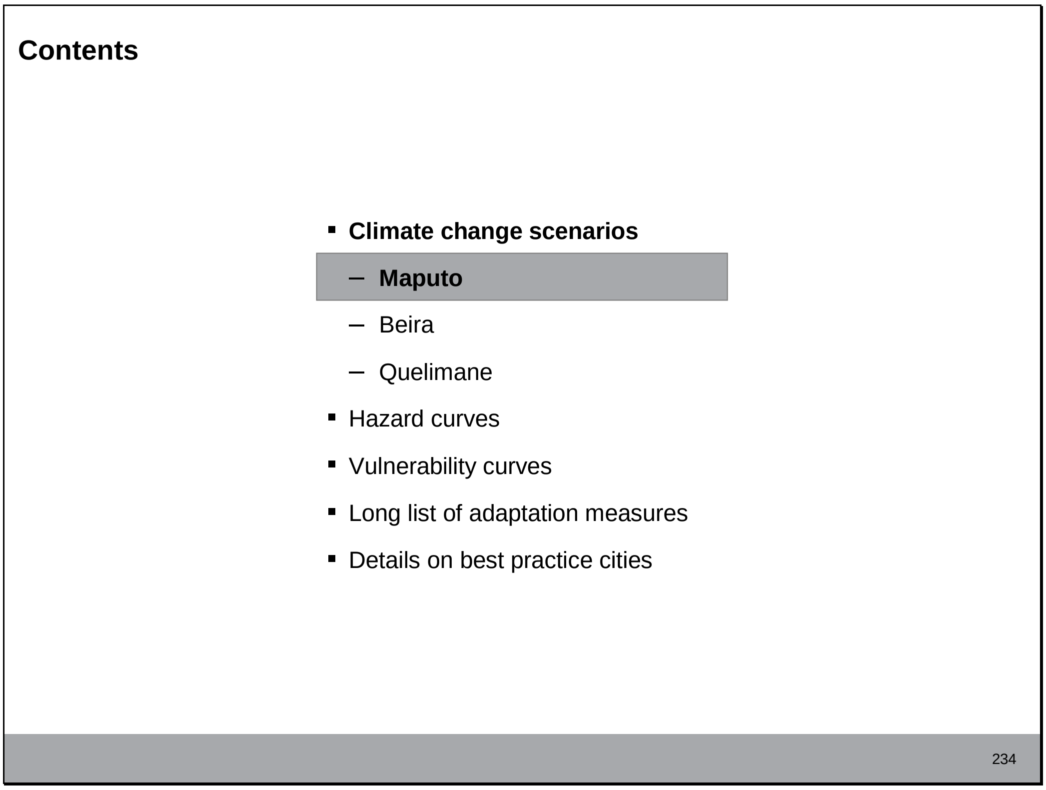
SLIDE 234



Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

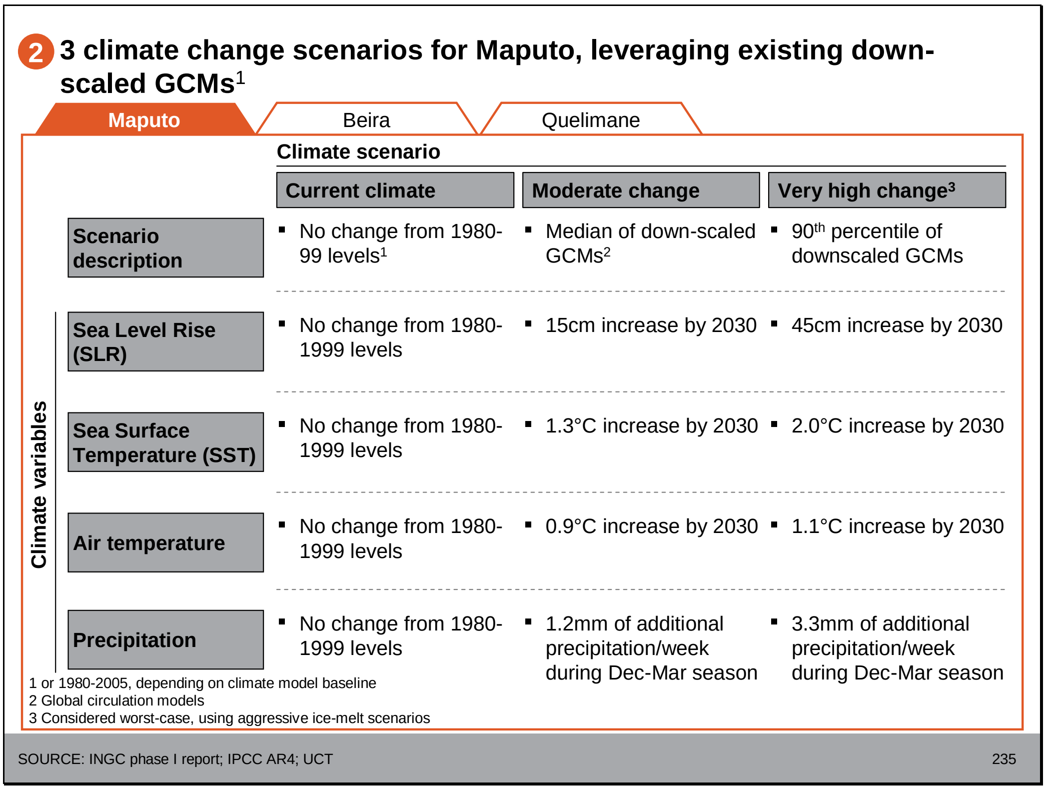
SLIDE 235



Contents

- **Climate change scenarios**
  - **Maputo**
  - Beira
  - Quelimane
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 236



② 3 climate change scenarios for Maputo, leveraging existing down-scaled GCMs[1]

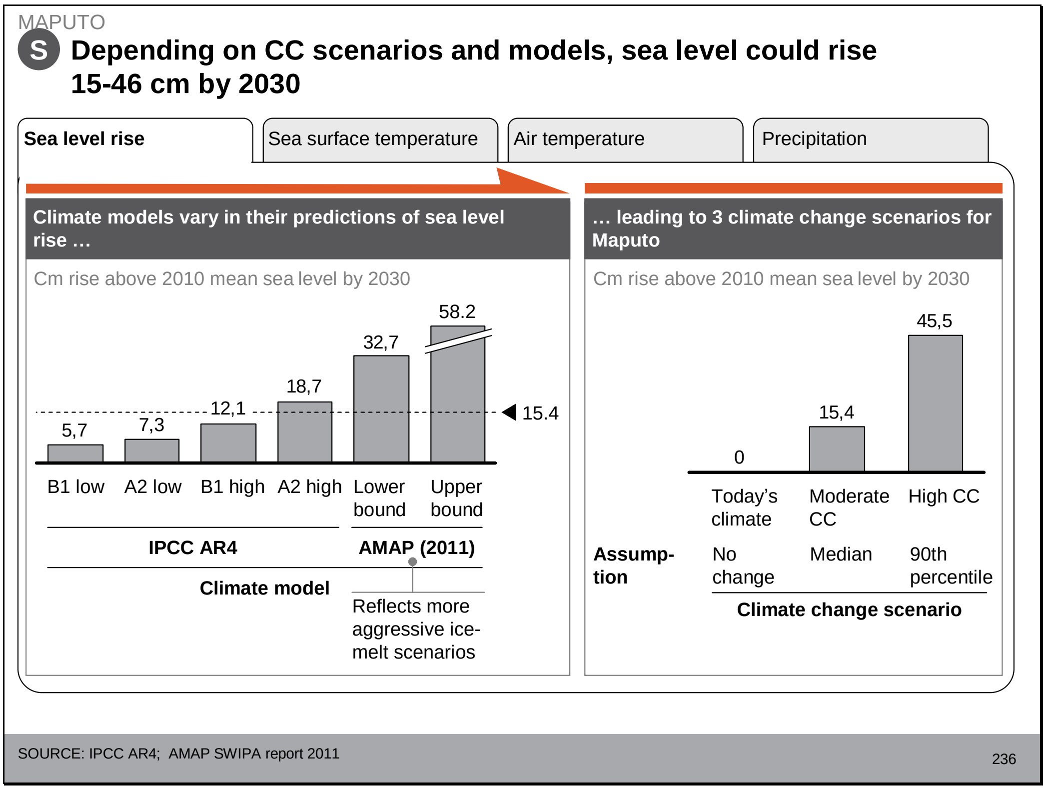
Maputo | Beira | Quelimane

		Climate scenario		
		Current climate	**Moderate change**	**Very high change[3]**
	Scenario description	No change from 1980-99 levels[1]	Median of down-scaled GCMs[2]	90th percentile of downscaled GCMs
Climate variables	**Sea Level Rise (SLR)**	No change from 1980-1999 levels	15cm increase by 2030	45cm increase by 2030
	Sea Surface Temperature (SST)	No change from 1980-1999 levels	1.3°C increase by 2030	2.0°C increase by 2030
	Air temperature	No change from 1980-1999 levels	0.9°C increase by 2030	1.1°C increase by 2030
	Precipitation	No change from 1980-1999 levels	1.2mm of additional precipitation/week during Dec-Mar season	3.3mm of additional precipitation/week during Dec-Mar season

1 or 1980-2005, depending on climate model baseline
2 Global circulation models
3 Considered worst-case, using aggressive ice-melt scenarios

SOURCE: INGC phase I report; IPCC AR4; UCT

SLIDE 237



MAPUTO

S Depending on CC scenarios and models, sea level could rise 15-46 cm by 2030

Climate models vary in their predictions of sea level rise …

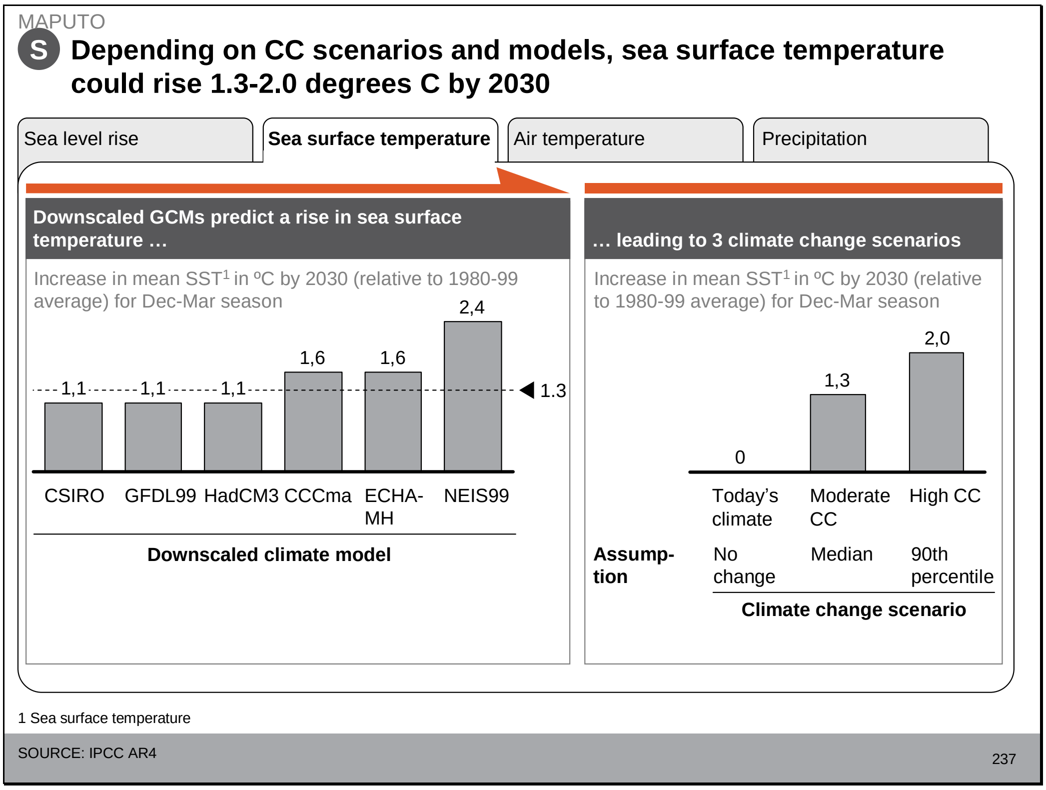
Cm rise above 2010 mean sea level by 2030

… leading to 3 climate change scenarios for Maputo

Cm rise above 2010 mean sea level by 2030

SOURCE: IPCC AR4; AMAP SWIPA report 2011

SLIDE 238



MAPUTO

S Depending on CC scenarios and models, sea surface temperature could rise 1.3-2.0 degrees C by 2030

Downscaled GCMs predict a rise in sea surface temperature …

Increase in mean SST[1] in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

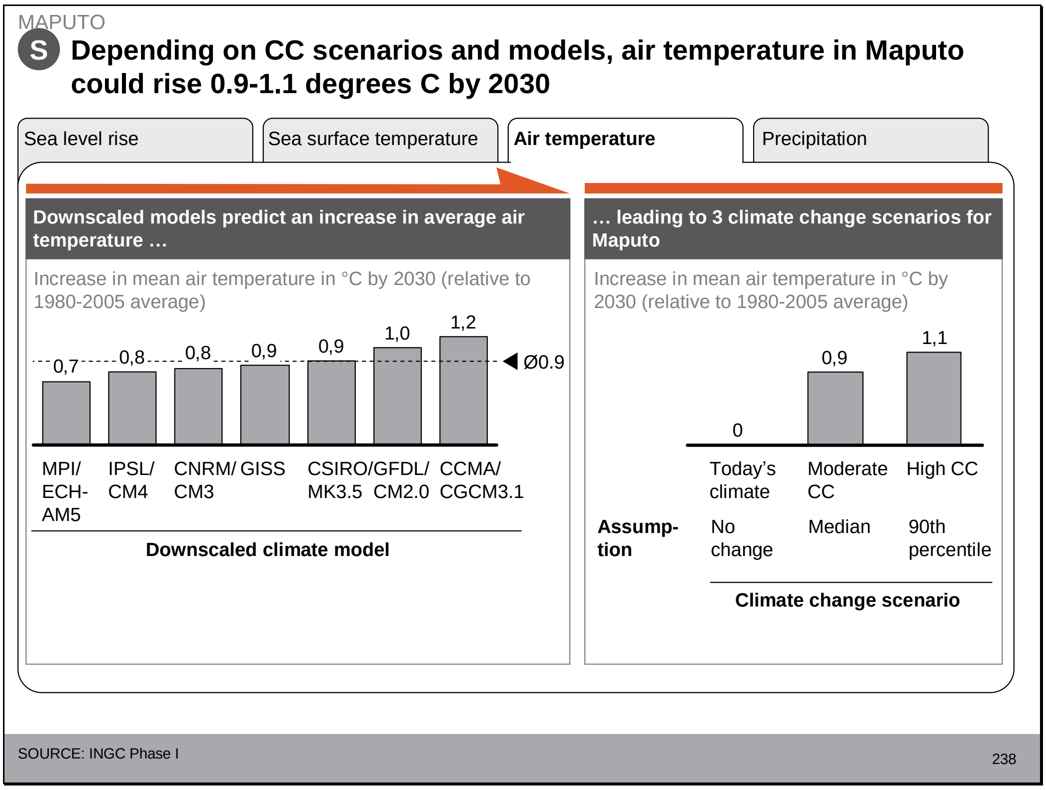
… leading to 3 climate change scenarios

Increase in mean SST[1] in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

1 Sea surface temperature

SOURCE: IPCC AR4

SLIDE 239



MAPUTO

S Depending on CC scenarios and models, air temperature in Maputo could rise 0.9-1.1 degrees C by 2030

Sea level rise | Sea surface temperature | **Air temperature** | Precipitation

Downscaled models predict an increase in average air temperature …

Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

	MPI/ ECH-AM5	IPSL/ CM4	CNRM/ CM3	GISS	CSIRO/ MK3.5	GFDL/ CM2.0	CCMA/ CGCM3.1
	0,7	0,8	0,8	0,9	0,9	1,0	1,2

Ø0.9

Downscaled climate model

… leading to 3 climate change scenarios for Maputo

Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

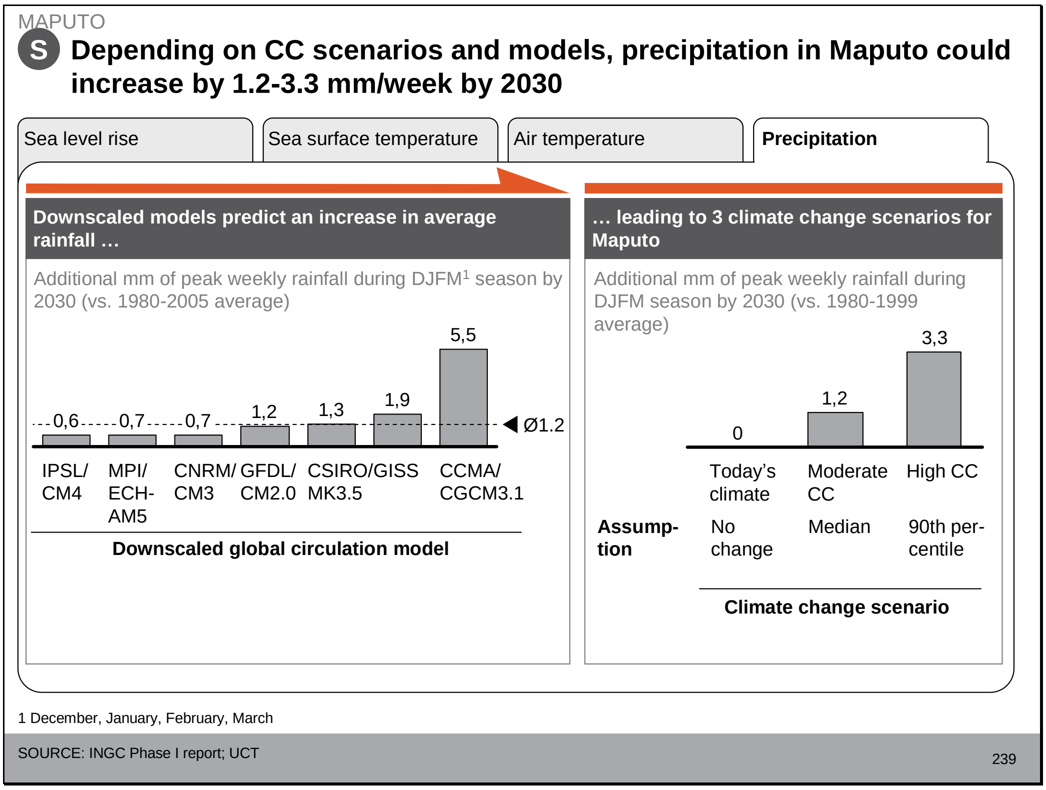
	Today's climate	Moderate CC	High CC
	0	0,9	1,1
Assump-tion	No change	Median	90th percentile

Climate change scenario

SOURCE: INGC Phase I

238

SLIDE 240



MAPUTO

S Depending on CC scenarios and models, precipitation in Maputo could increase by 1.2-3.3 mm/week by 2030

Sea level rise | Sea surface temperature | Air temperature | **Precipitation**

Downscaled models predict an increase in average rainfall …

Additional mm of peak weekly rainfall during DJFM[1] season by 2030 (vs. 1980-2005 average)

	IPSL/ CM4	MPI/ ECH-AM5	CNRM/ CM3	GFDL/ CM2.0	CSIRO/ MK3.5	GISS	CCMA/ CGCM3.1
	0,6	0,7	0,7	1,2	1,3	1,9	5,5

Ø1.2

Downscaled global circulation model

… leading to 3 climate change scenarios for Maputo

Additional mm of peak weekly rainfall during DJFM season by 2030 (vs. 1980-1999 average)

	Today's climate	Moderate CC	High CC
	0	1,2	3,3
Assump-tion	No change	Median	90th per-centile

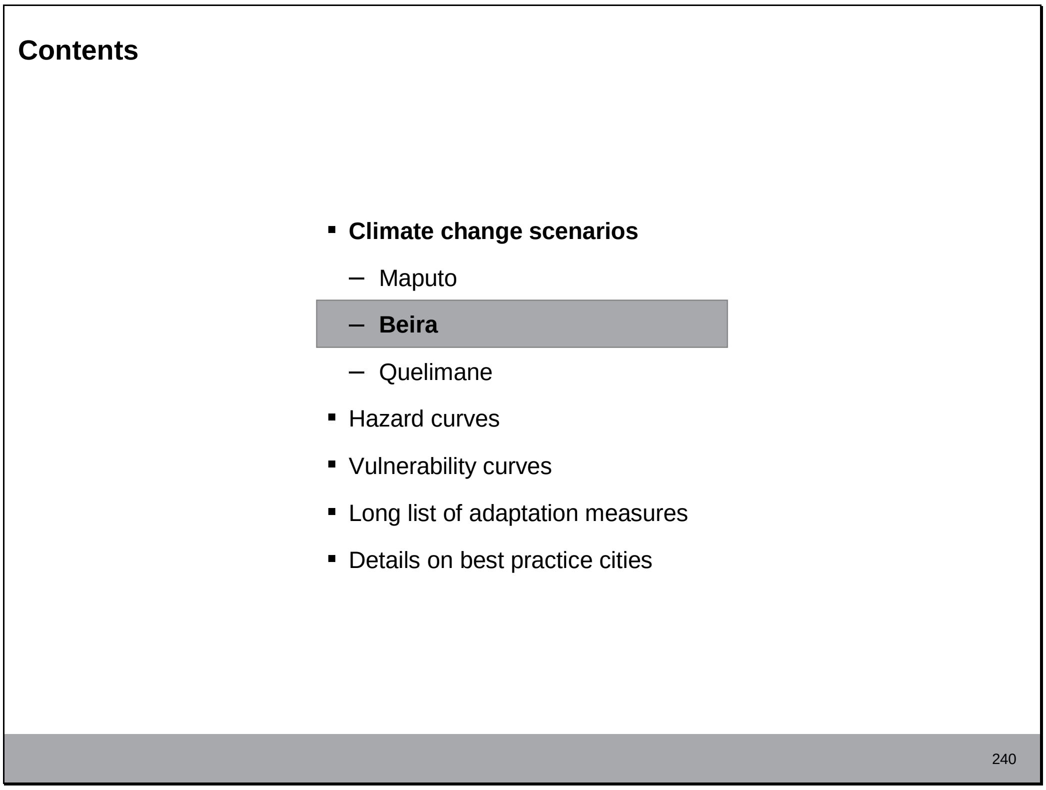
Climate change scenario

1 December, January, February, March

SOURCE: INGC Phase I report; UCT

239

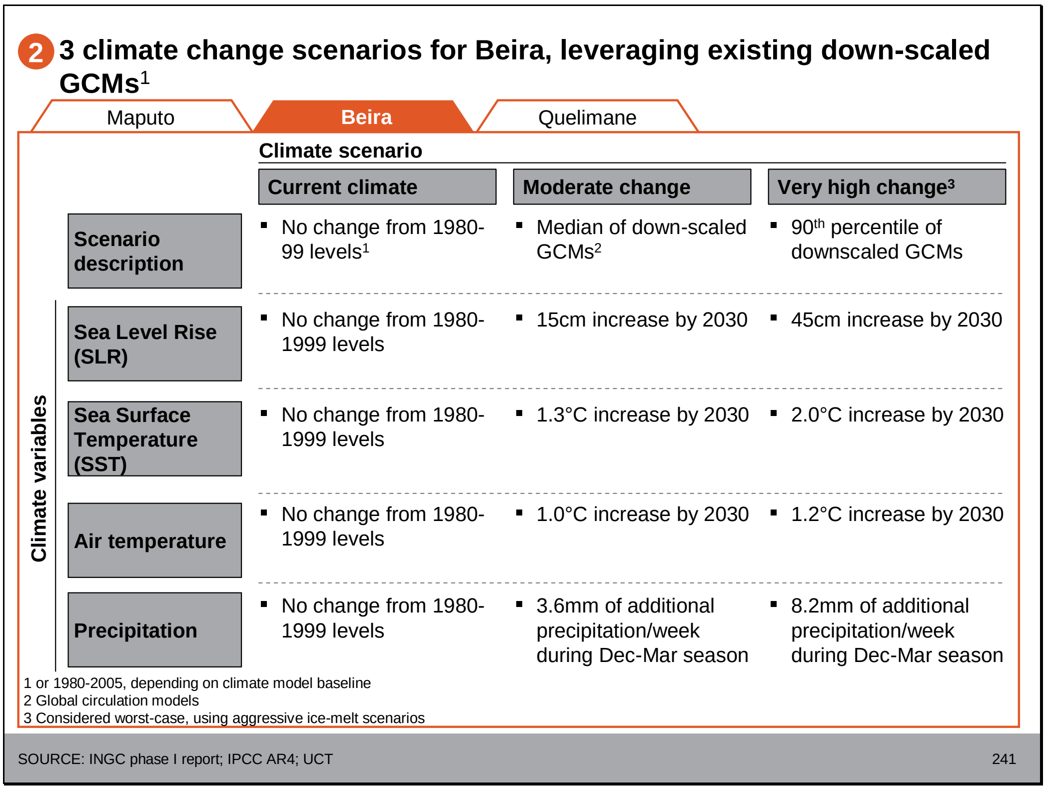
SLIDE 241



Contents

- **Climate change scenarios**
  - Maputo
  - **Beira**
  - Quelimane
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 242



② 3 climate change scenarios for Beira, leveraging existing down-scaled GCMs[1]

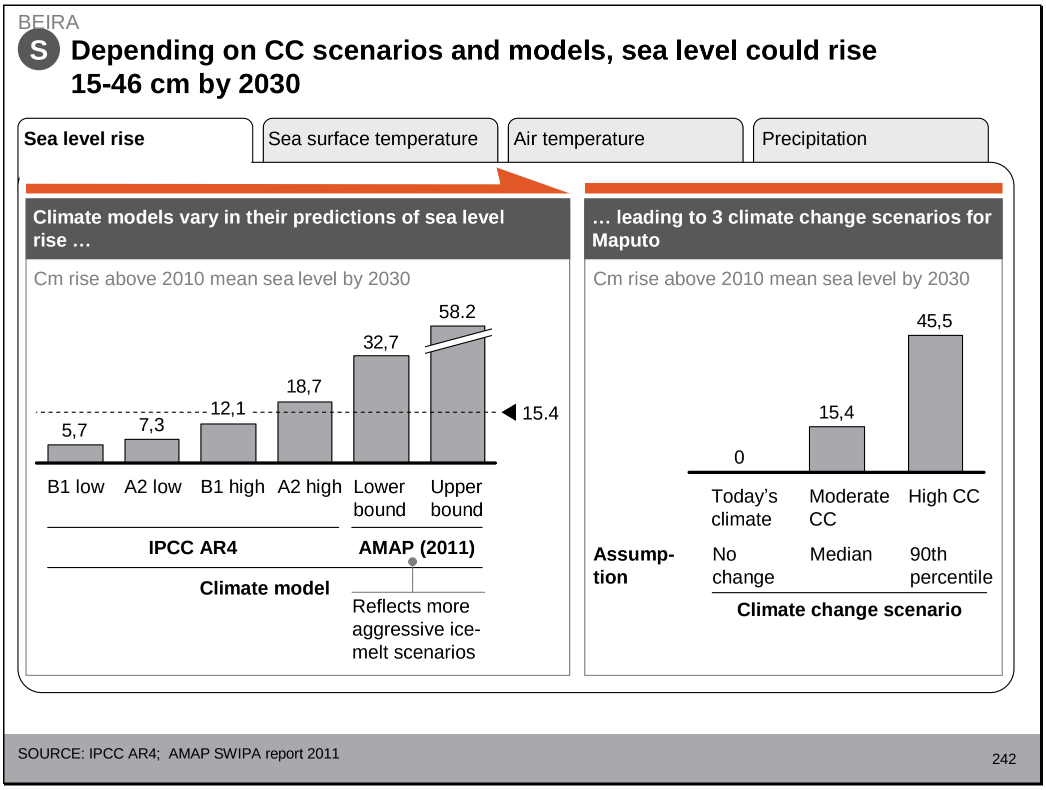
Maputo | **Beira** | Quelimane

		Climate scenario		
		Current climate	**Moderate change**	**Very high change[3]**
	Scenario description	No change from 1980-99 levels[1]	Median of down-scaled GCMs[2]	90th percentile of downscaled GCMs
Climate variables	**Sea Level Rise (SLR)**	No change from 1980-1999 levels	15cm increase by 2030	45cm increase by 2030
	Sea Surface Temperature (SST)	No change from 1980-1999 levels	1.3°C increase by 2030	2.0°C increase by 2030
	Air temperature	No change from 1980-1999 levels	1.0°C increase by 2030	1.2°C increase by 2030
	Precipitation	No change from 1980-1999 levels	3.6mm of additional precipitation/week during Dec-Mar season	8.2mm of additional precipitation/week during Dec-Mar season

1 or 1980-2005, depending on climate model baseline
2 Global circulation models
3 Considered worst-case, using aggressive ice-melt scenarios

SOURCE: INGC phase I report; IPCC AR4; UCT

SLIDE 243



BEIRA

Depending on CC scenarios and models, sea level could rise 15-46 cm by 2030

Sea level rise | Sea surface temperature | Air temperature | Precipitation

Climate models vary in their predictions of sea level rise …

Cm rise above 2010 mean sea level by 2030

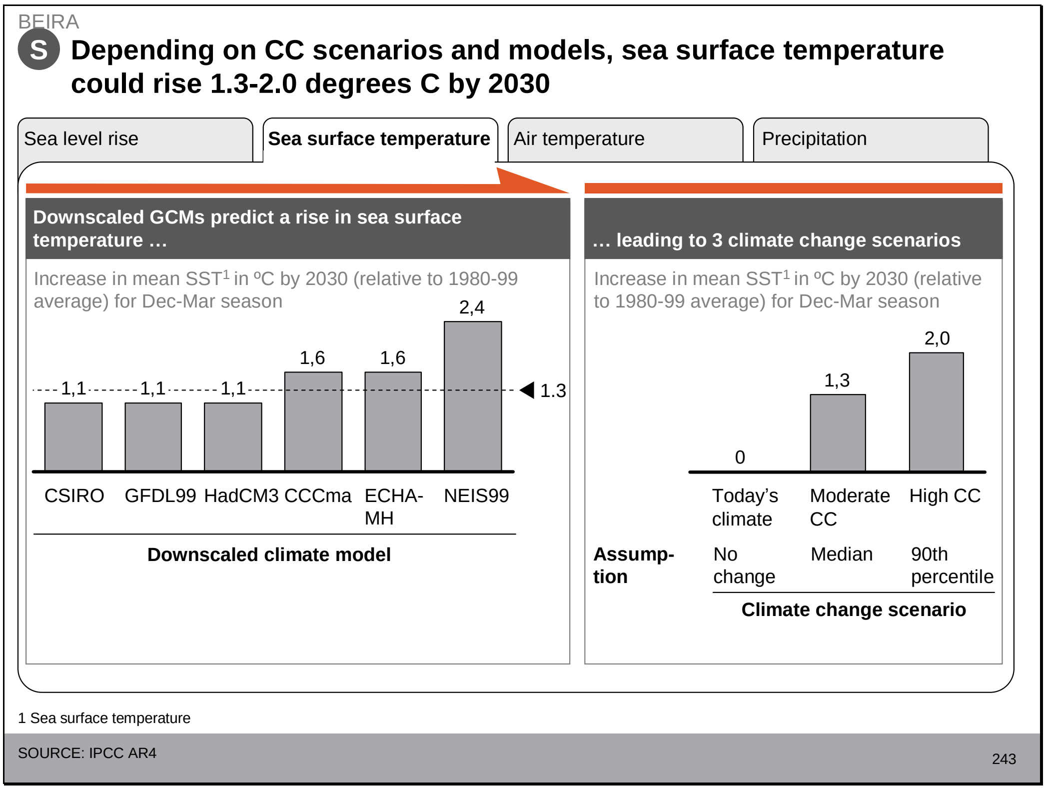
… leading to 3 climate change scenarios for Maputo

Cm rise above 2010 mean sea level by 2030

SOURCE: IPCC AR4; AMAP SWIPA report 2011

242

SLIDE 244



BEIRA

Depending on CC scenarios and models, sea surface temperature could rise 1.3-2.0 degrees C by 2030

Sea level rise | **Sea surface temperature** | Air temperature | Precipitation

Downscaled GCMs predict a rise in sea surface temperature …

Increase in mean SST[1] in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

… leading to 3 climate change scenarios

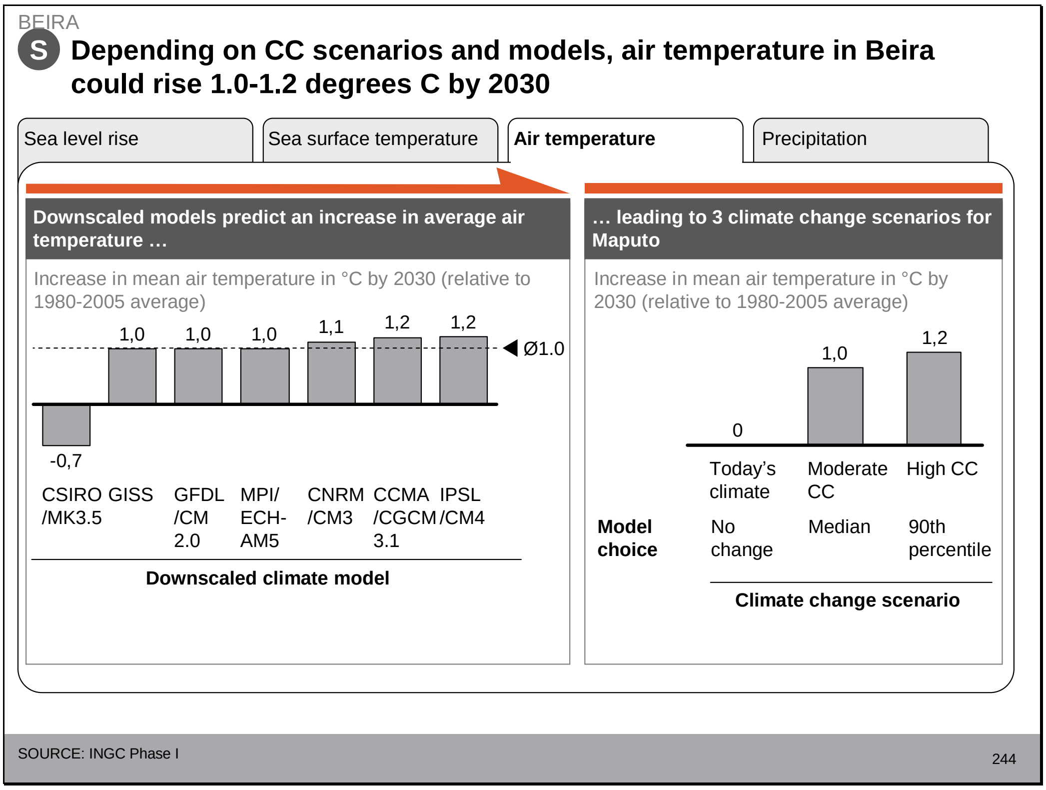
Increase in mean SST[1] in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

[1] Sea surface temperature

SOURCE: IPCC AR4

243

SLIDE 245



BEIRA

Depending on CC scenarios and models, air temperature in Beira could rise 1.0-1.2 degrees C by 2030

Sea level rise | Sea surface temperature | **Air temperature** | Precipitation

Downscaled models predict an increase in average air temperature …

Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

Downscaled climate model

… leading to 3 climate change scenarios for Maputo

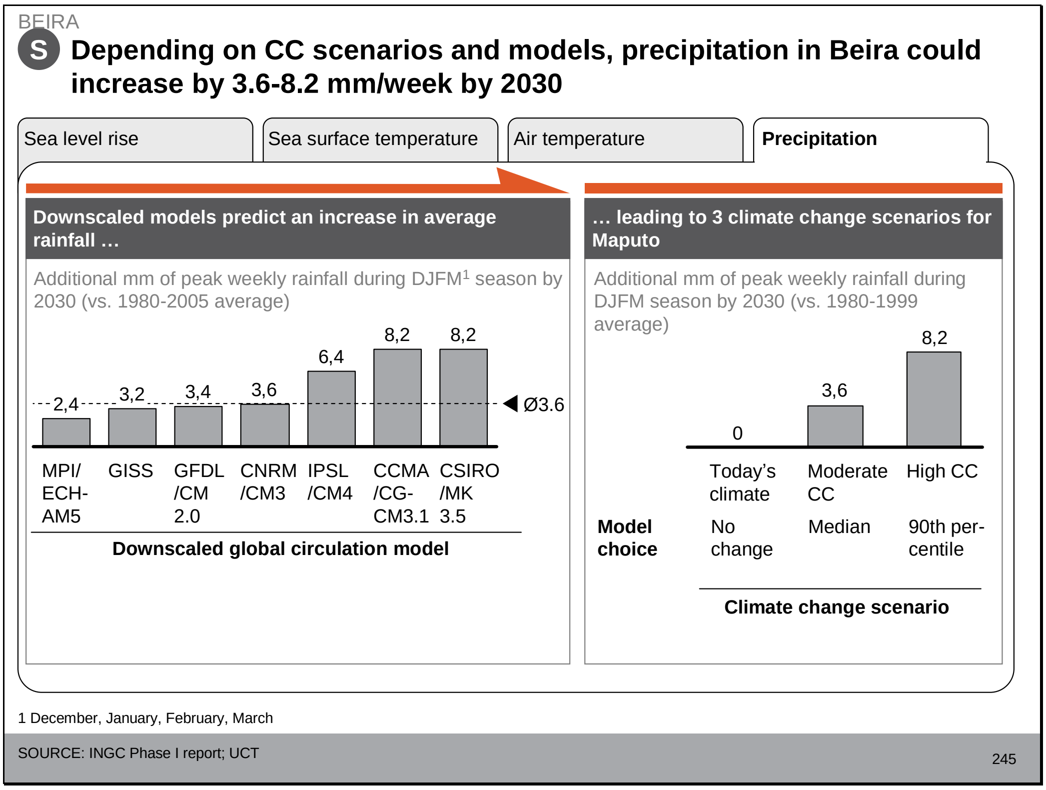
Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

Model choice	No change	Median	90th percentile

Climate change scenario

SOURCE: INGC Phase I

SLIDE 246



BEIRA

Depending on CC scenarios and models, precipitation in Beira could increase by 3.6-8.2 mm/week by 2030

Sea level rise | Sea surface temperature | Air temperature | **Precipitation**

Downscaled models predict an increase in average rainfall …

Additional mm of peak weekly rainfall during DJFM[1] season by 2030 (vs. 1980-2005 average)

Downscaled global circulation model

… leading to 3 climate change scenarios for Maputo

Additional mm of peak weekly rainfall during DJFM season by 2030 (vs. 1980-1999 average)

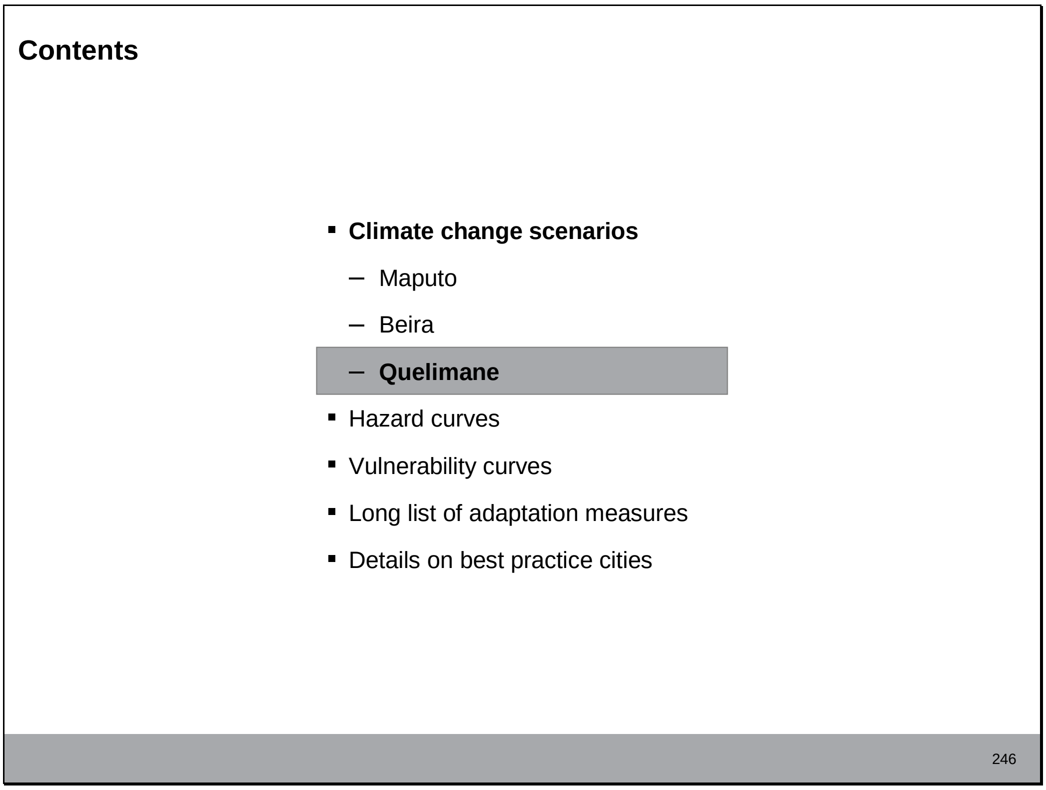
Model choice	No change	Median	90th percentile

Climate change scenario

[1] December, January, February, March

SOURCE: INGC Phase I report; UCT

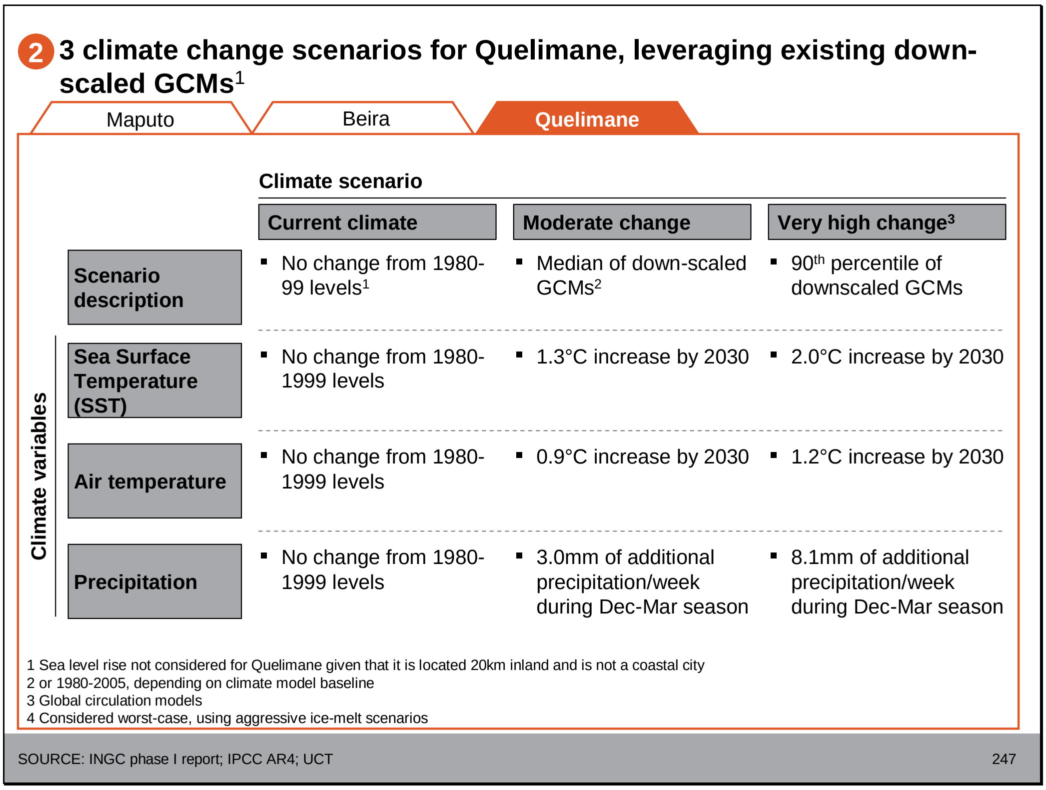
SLIDE 247



Contents

- **Climate change scenarios**
  - Maputo
  - Beira
  - **Quelimane**
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 248



② 3 climate change scenarios for Quelimane, leveraging existing down-scaled GCMs[1]

Maputo | Beira | **Quelimane**

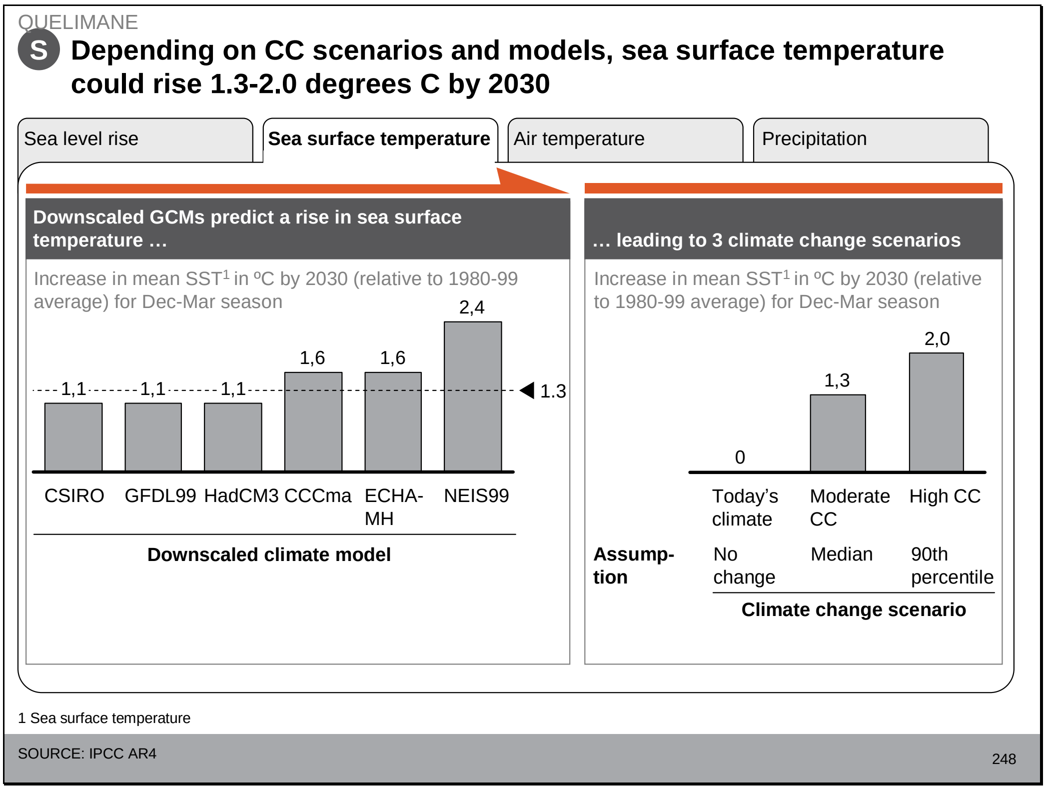
Climate scenario

	Current climate	**Moderate change**	**Very high change[3]**
Scenario description	No change from 1980-99 levels[1]	Median of down-scaled GCMs[2]	90th percentile of downscaled GCMs
Climate variables: Sea Surface Temperature (SST)	No change from 1980-1999 levels	1.3°C increase by 2030	2.0°C increase by 2030
Climate variables: Air temperature	No change from 1980-1999 levels	0.9°C increase by 2030	1.2°C increase by 2030
Climate variables: Precipitation	No change from 1980-1999 levels	3.0mm of additional precipitation/week during Dec-Mar season	8.1mm of additional precipitation/week during Dec-Mar season

1 Sea level rise not considered for Quelimane given that it is located 20km inland and is not a coastal city
2 or 1980-2005, depending on climate model baseline
3 Global circulation models
4 Considered worst-case, using aggressive ice-melt scenarios

SOURCE: INGC phase I report; IPCC AR4; UCT

SLIDE 249



QUELIMANE

S Depending on CC scenarios and models, sea surface temperature could rise 1.3-2.0 degrees C by 2030

Sea level rise | **Sea surface temperature** | Air temperature | Precipitation

Downscaled GCMs predict a rise in sea surface temperature …

Increase in mean SST¹ in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

Downscaled climate model

… leading to 3 climate change scenarios

Increase in mean SST¹ in ºC by 2030 (relative to 1980-99 average) for Dec-Mar season

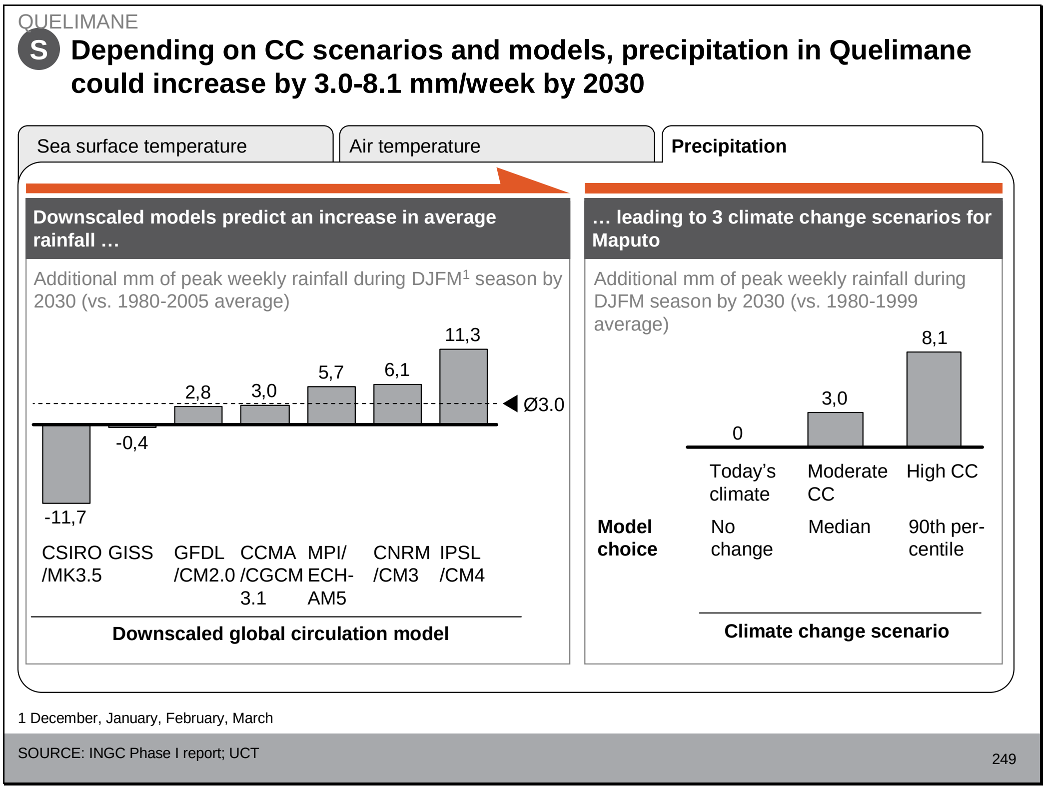
Assumption No change | Median | 90th percentile

Climate change scenario

1 Sea surface temperature

SOURCE: IPCC AR4

SLIDE 250



QUELIMANE

S Depending on CC scenarios and models, precipitation in Quelimane could increase by 3.0-8.1 mm/week by 2030

Sea surface temperature | Air temperature | **Precipitation**

Downscaled models predict an increase in average rainfall …

Additional mm of peak weekly rainfall during DJFM¹ season by 2030 (vs. 1980-2005 average)

Downscaled global circulation model

… leading to 3 climate change scenarios for Maputo

Additional mm of peak weekly rainfall during DJFM season by 2030 (vs. 1980-1999 average)

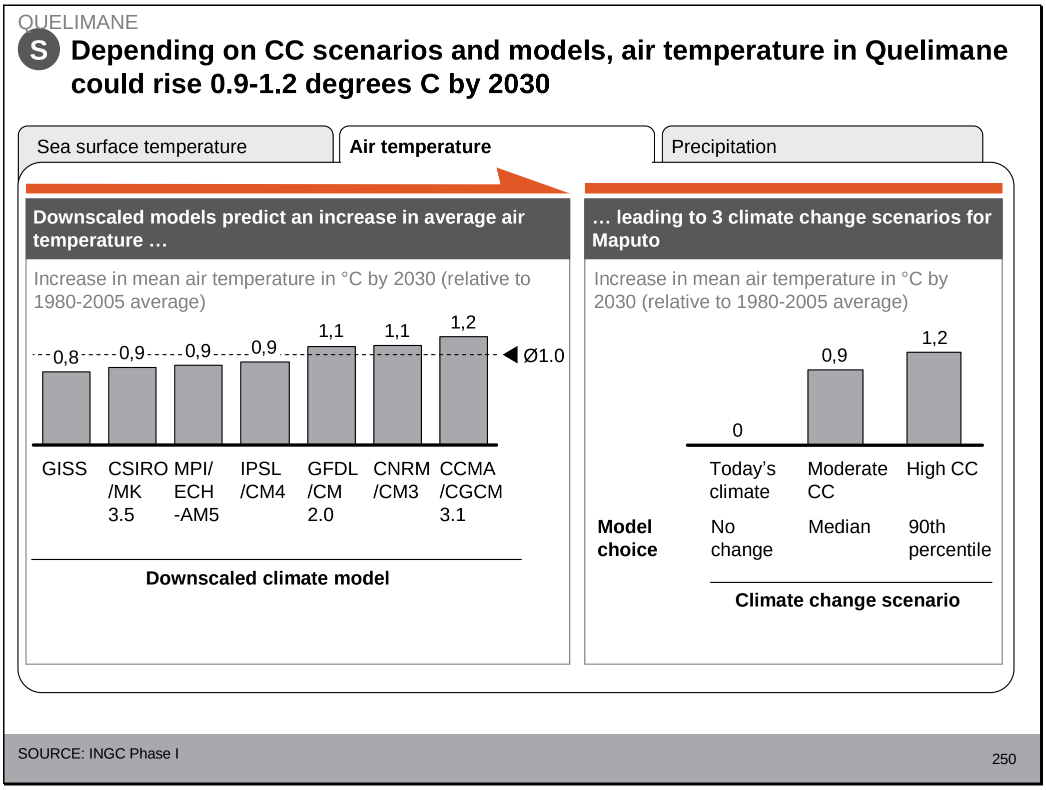
Model choice No change | Median | 90th percentile

Climate change scenario

1 December, January, February, March

SOURCE: INGC Phase I report; UCT

SLIDE 251



QUELIMANE

S **Depending on CC scenarios and models, air temperature in Quelimane could rise 0.9-1.2 degrees C by 2030**

Sea surface temperature | **Air temperature** | Precipitation

Downscaled models predict an increase in average air temperature …

Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

… leading to 3 climate change scenarios for Maputo

Increase in mean air temperature in °C by 2030 (relative to 1980-2005 average)

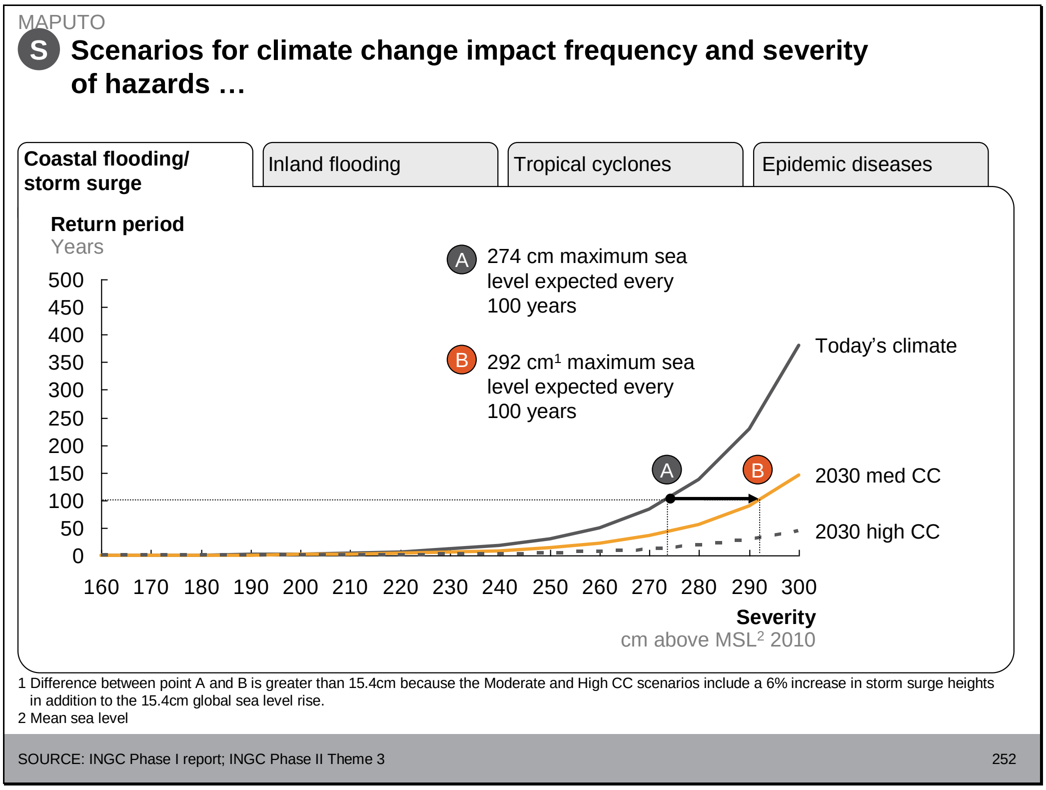
SOURCE: INGC Phase I

SLIDE 252

Contents

- Climate change scenarios
- **Hazard curves**
  - **Maputo**
  - Beira
  - Quelimane
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 253



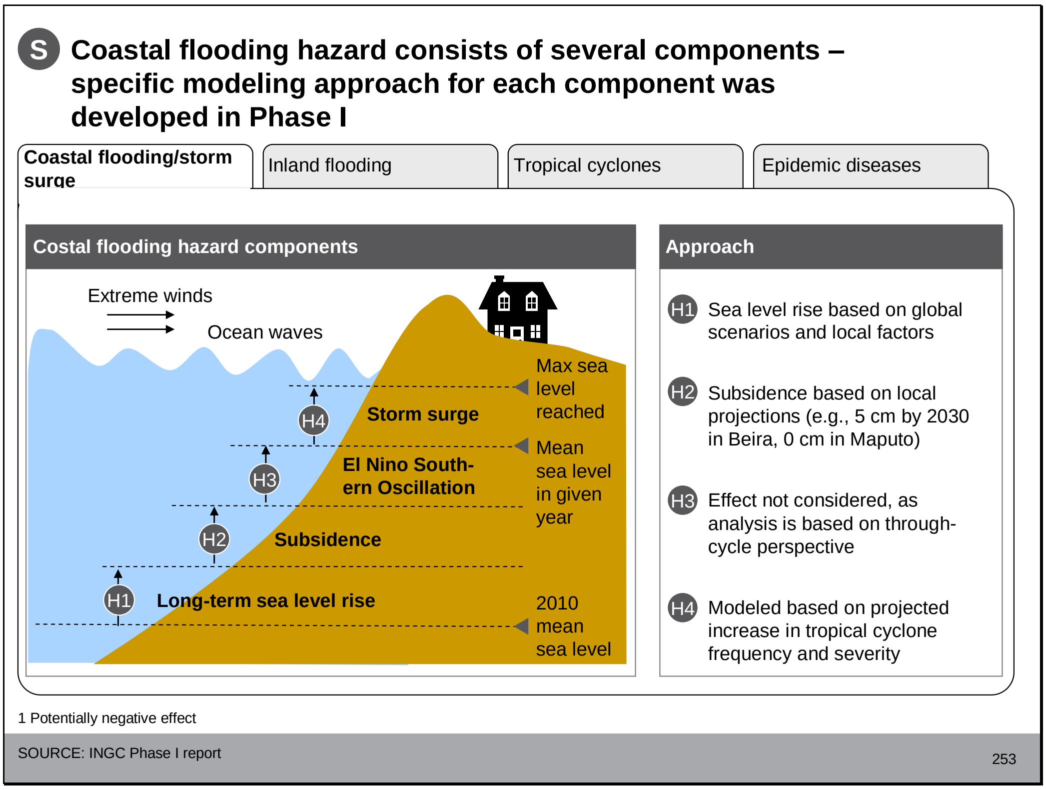
MAPUTO

S **Scenarios for climate change impact frequency and severity of hazards …**

1 Difference between point A and B is greater than 15.4cm because the Moderate and High CC scenarios include a 6% increase in storm surge heights in addition to the 15.4cm global sea level rise.
2 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II Theme 3

SLIDE 254



S **Coastal flooding hazard consists of several components – specific modeling approach for each component was developed in Phase I**

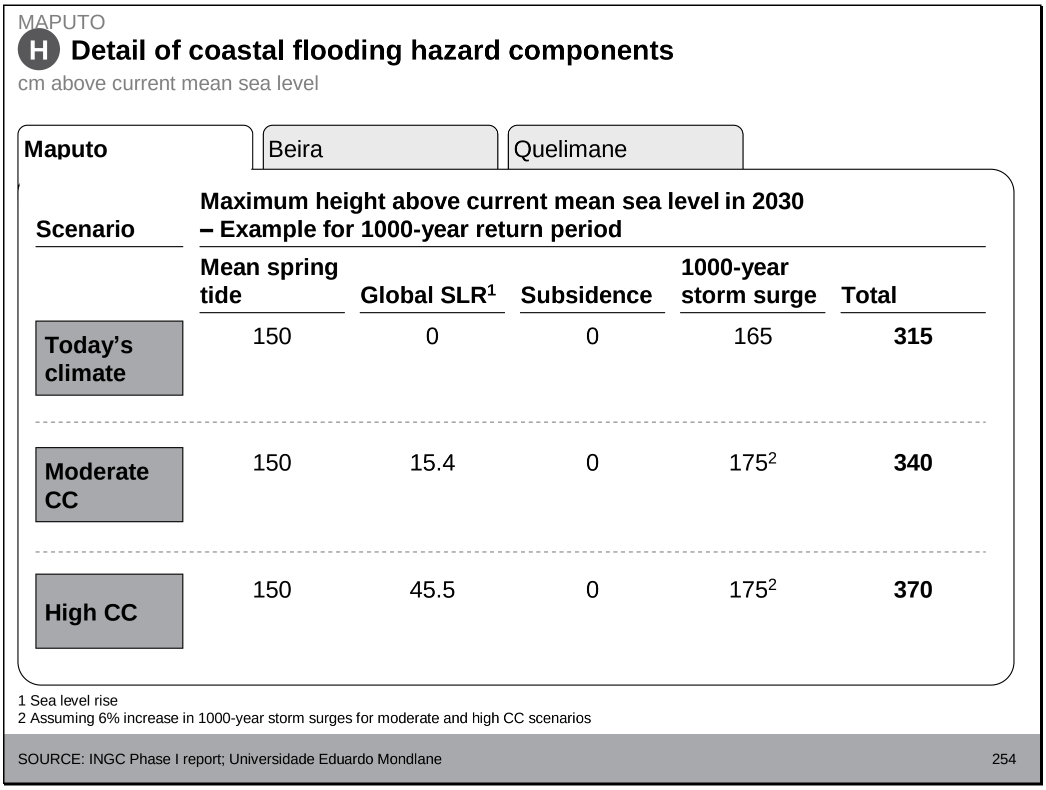
Approach

- H1 Sea level rise based on global scenarios and local factors
- H2 Subsidence based on local projections (e.g., 5 cm by 2030 in Beira, 0 cm in Maputo)
- H3 Effect not considered, as analysis is based on through-cycle perspective
- H4 Modeled based on projected increase in tropical cyclone frequency and severity

1 Potentially negative effect

SOURCE: INGC Phase I report

SLIDE 255



MAPUTO

H Detail of coastal flooding hazard components

cm above current mean sea level

Maputo | Beira | Quelimane

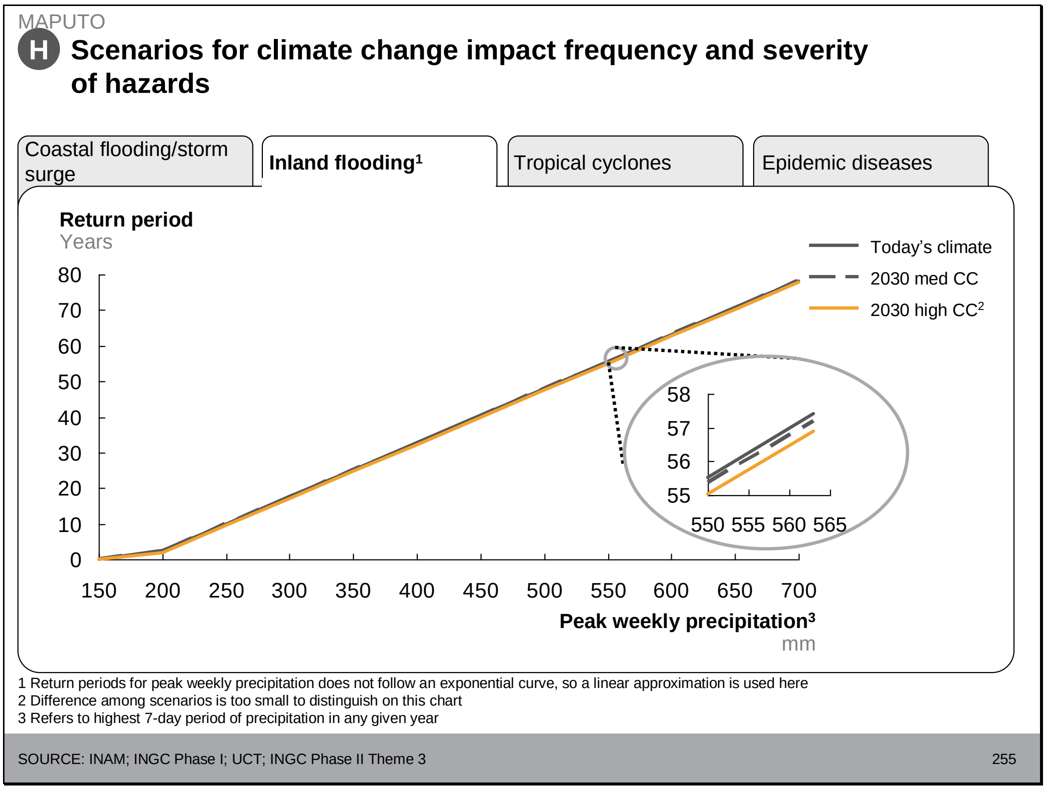
Scenario	Maximum height above current mean sea level in 2030 – Example for 1000-year return period				
	Mean spring tide	Global SLR[1]	Subsidence	1000-year storm surge	Total
Today's climate	150	0	0	165	**315**
Moderate CC	150	15.4	0	175[2]	**340**
High CC	150	45.5	0	175[2]	**370**

1 Sea level rise
2 Assuming 6% increase in 1000-year storm surges for moderate and high CC scenarios

SOURCE: INGC Phase I report; Universidade Eduardo Mondlane

254

SLIDE 256



MAPUTO

H Scenarios for climate change impact frequency and severity of hazards

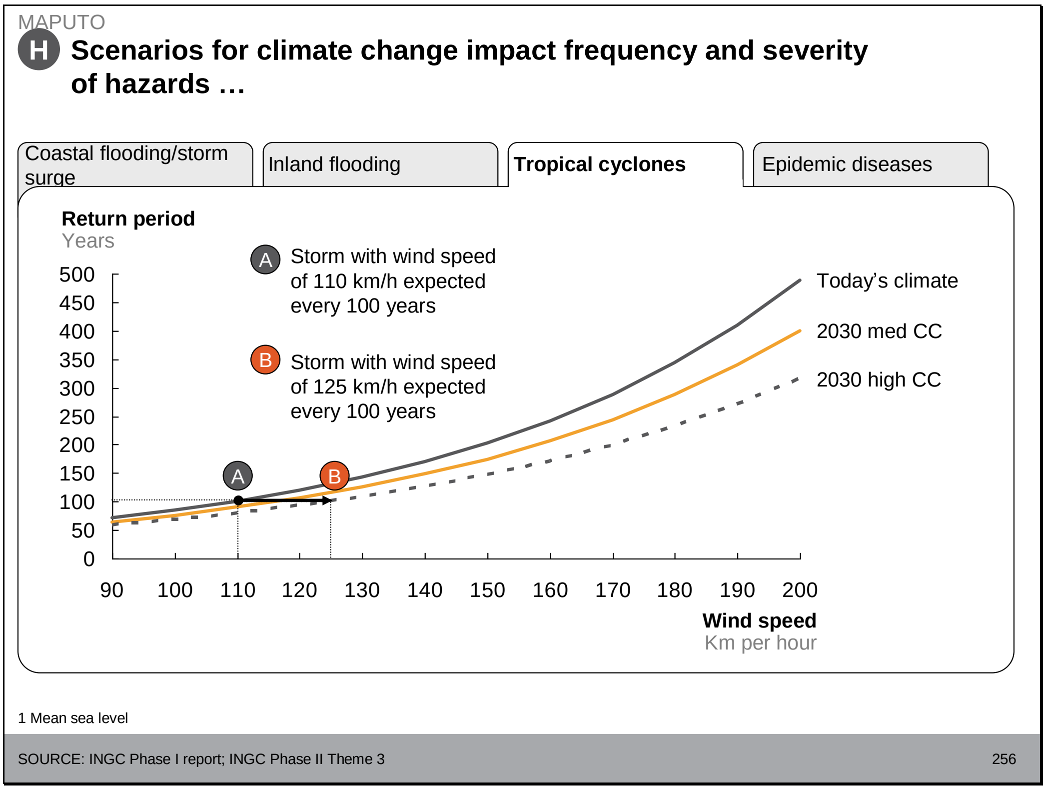
Coastal flooding/storm surge | **Inland flooding[1]** | Tropical cyclones | Epidemic diseases

1 Return periods for peak weekly precipitation does not follow an exponential curve, so a linear approximation is used here
2 Difference among scenarios is too small to distinguish on this chart
3 Refers to highest 7-day period of precipitation in any given year

SOURCE: INAM; INGC Phase I; UCT; INGC Phase II Theme 3

255

SLIDE 257



MAPUTO

H Scenarios for climate change impact frequency and severity of hazards …

Coastal flooding/storm surge | Inland flooding | **Tropical cyclones** | Epidemic diseases

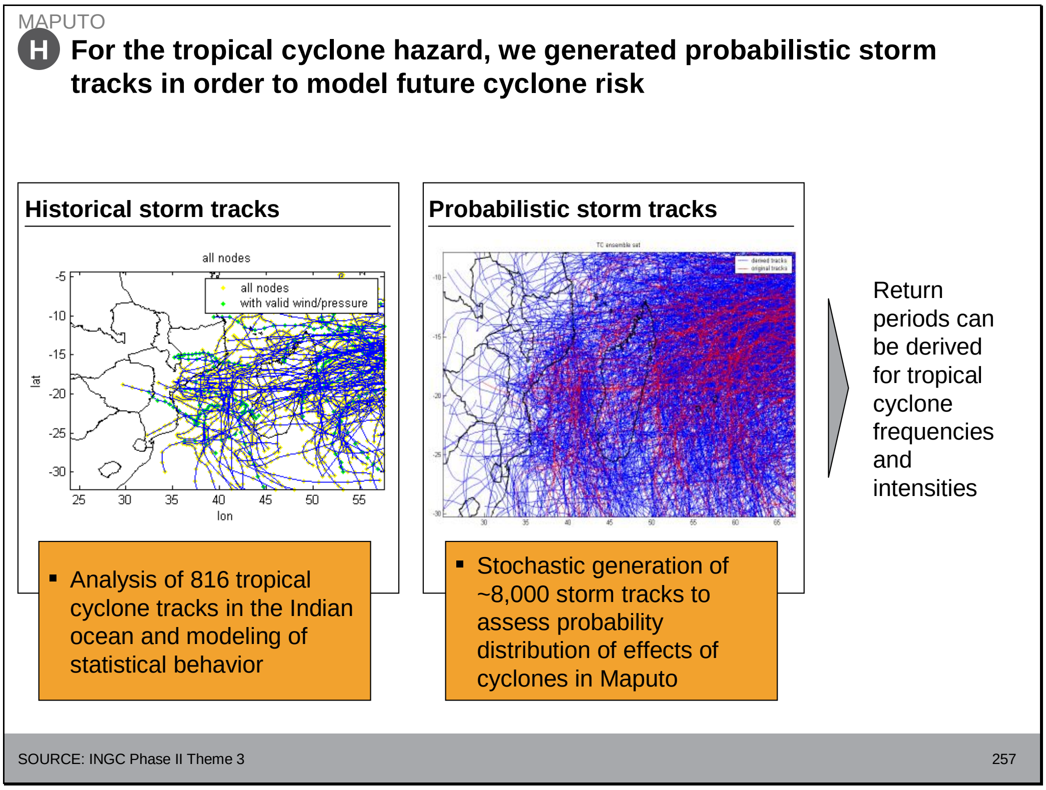
A Storm with wind speed of 110 km/h expected every 100 years

B Storm with wind speed of 125 km/h expected every 100 years

1 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II Theme 3

SLIDE 258



MAPUTO

H For the tropical cyclone hazard, we generated probabilistic storm tracks in order to model future cyclone risk

Historical storm tracks

- Analysis of 816 tropical cyclone tracks in the Indian ocean and modeling of statistical behavior

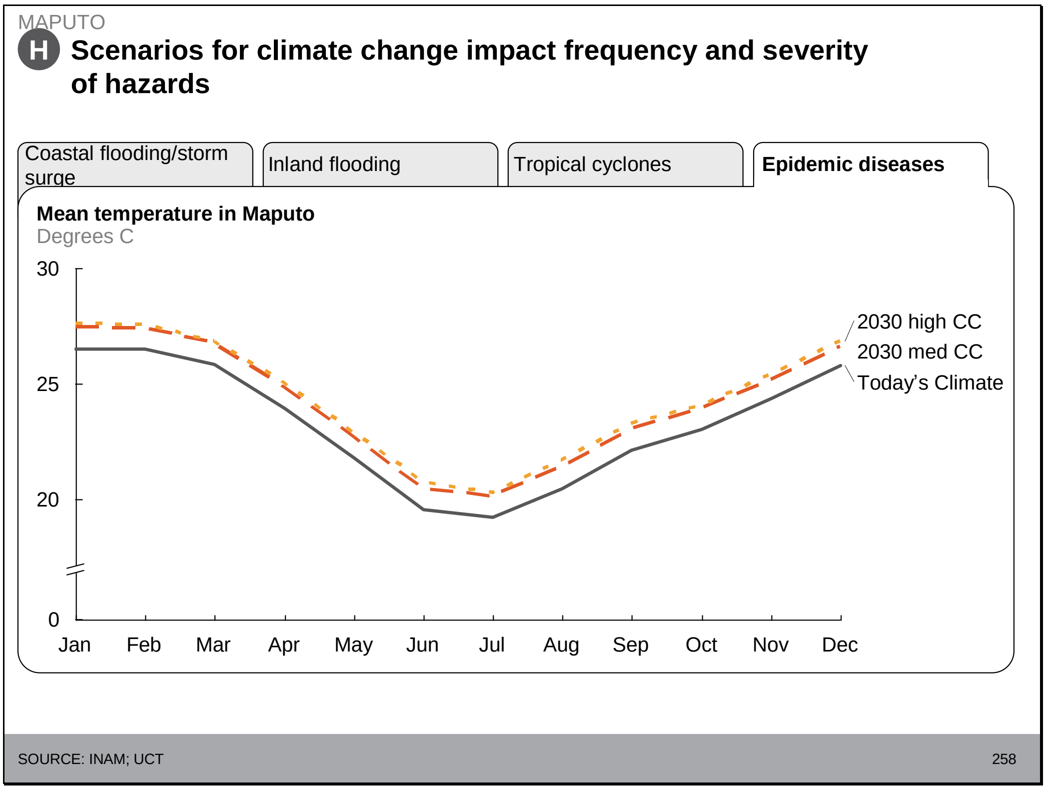
Probabilistic storm tracks

- Stochastic generation of ~8,000 storm tracks to assess probability distribution of effects of cyclones in Maputo

Return periods can be derived for tropical cyclone frequencies and intensities

SOURCE: INGC Phase II Theme 3

SLIDE 259

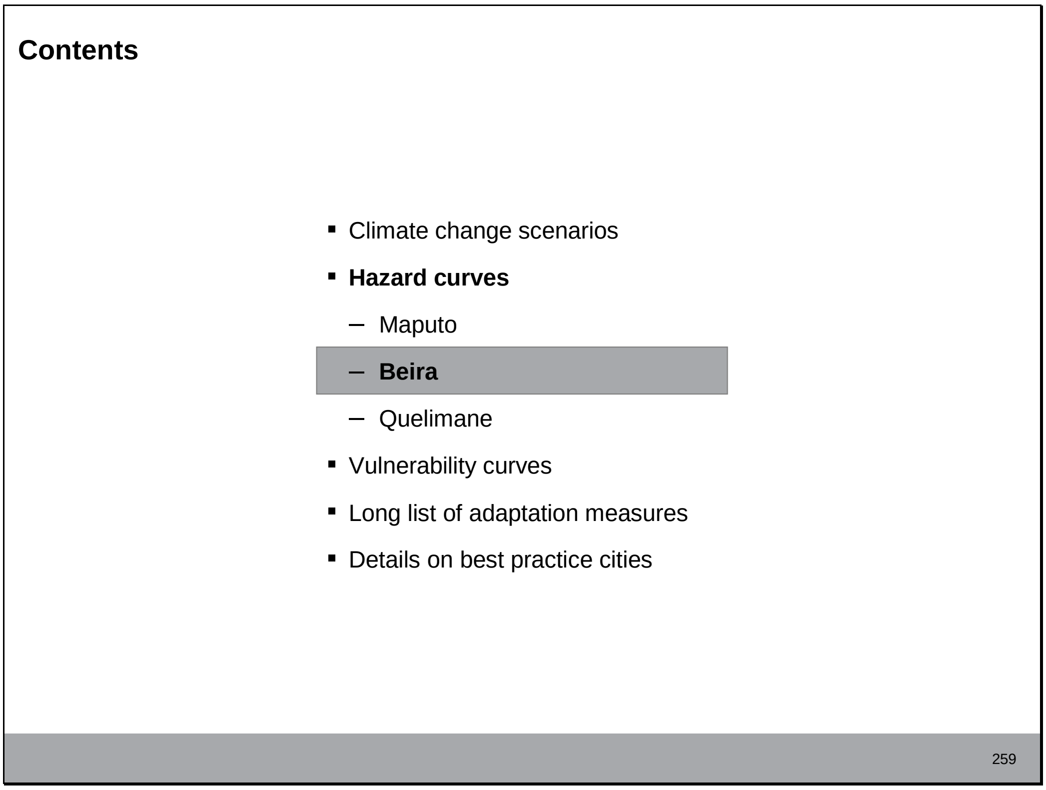


MAPUTO

H Scenarios for climate change impact frequency and severity of hazards

SOURCE: INAM; UCT

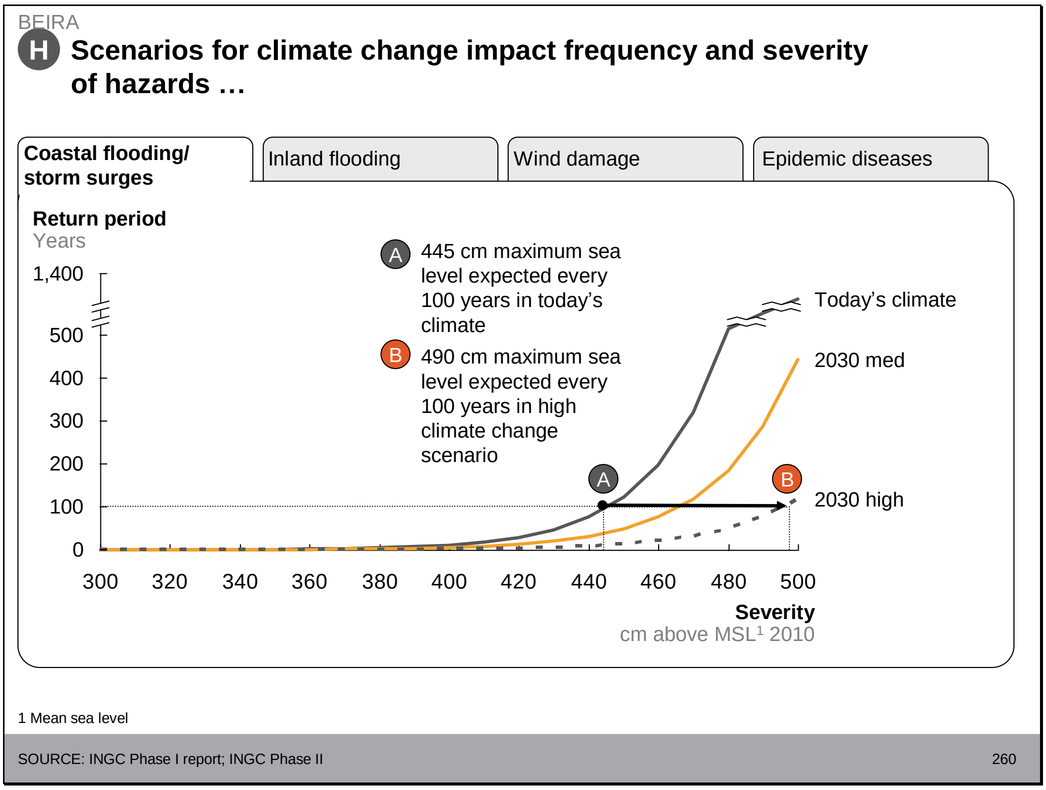
SLIDE 260



Contents

- Climate change scenarios
- **Hazard curves**
  - Maputo
  - **Beira**
  - Quelimane
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 261



BEIRA

H Scenarios for climate change impact frequency and severity of hazards …

Coastal flooding/ storm surges | Inland flooding | Wind damage | Epidemic diseases

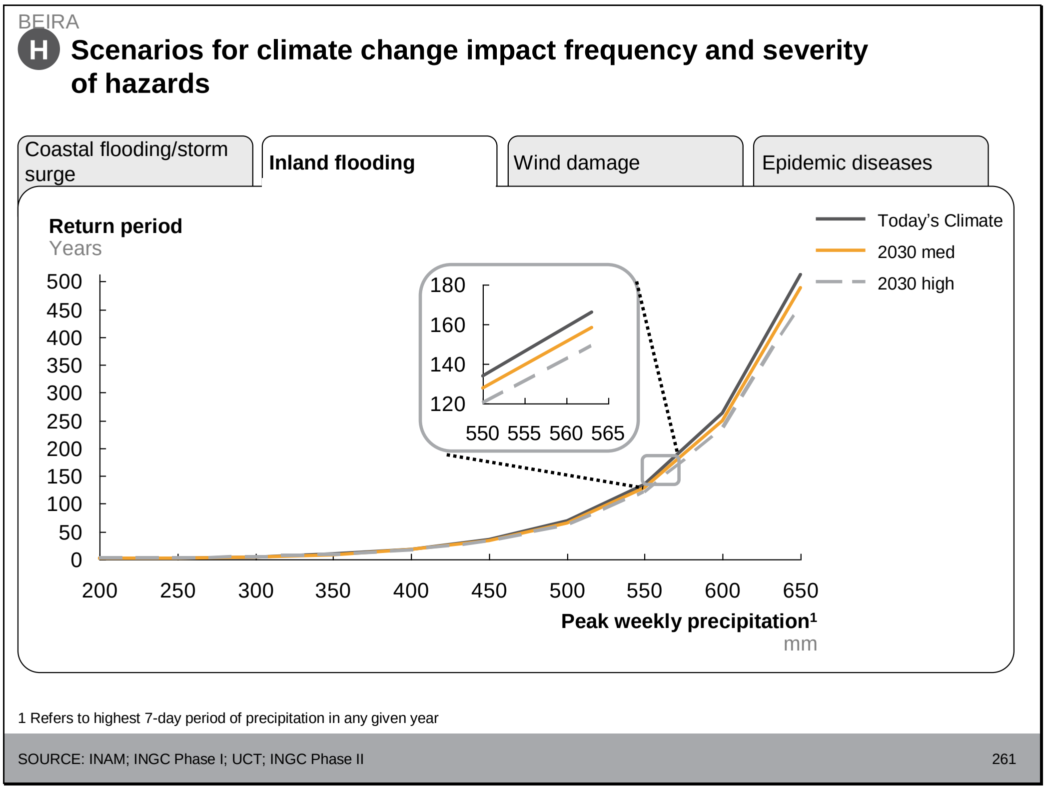
Ⓐ 445 cm maximum sea level expected every 100 years in today's climate

Ⓑ 490 cm maximum sea level expected every 100 years in high climate change scenario

1 Mean sea level

SOURCE: INGC Phase I report; INGC Phase II

SLIDE 262



BEIRA

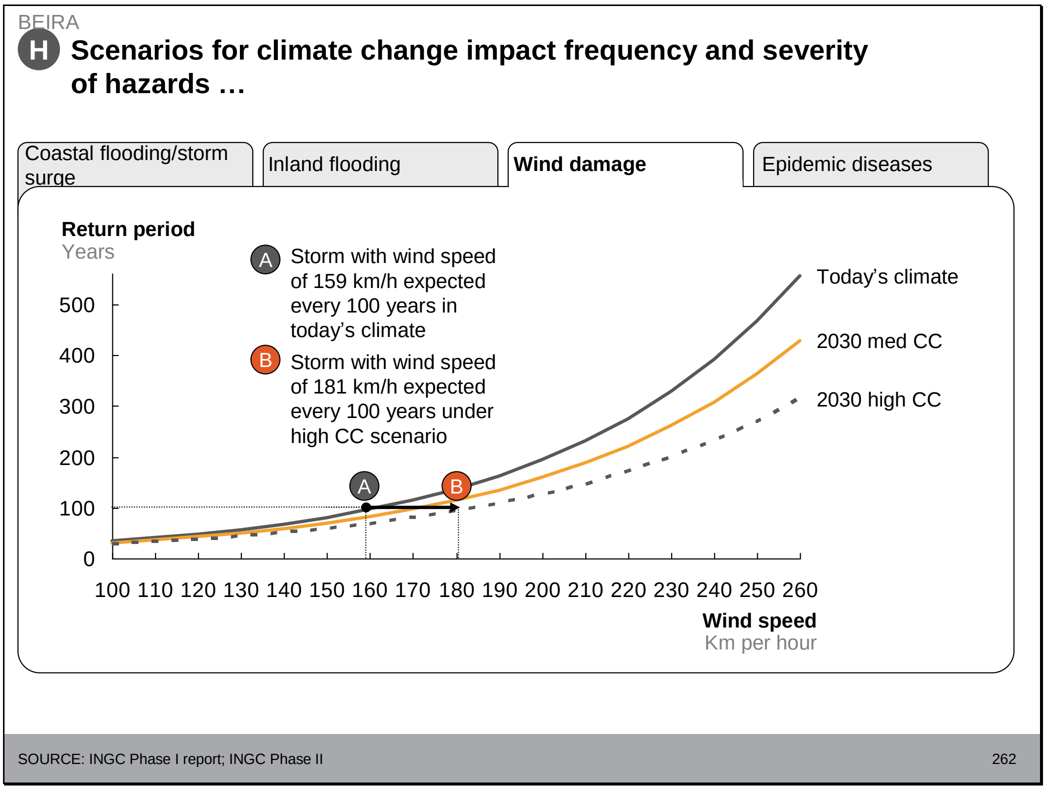
H Scenarios for climate change impact frequency and severity of hazards

Coastal flooding/storm surge | **Inland flooding** | Wind damage | Epidemic diseases

1 Refers to highest 7-day period of precipitation in any given year

SOURCE: INAM; INGC Phase I; UCT; INGC Phase II

SLIDE 263



BEIRA

H Scenarios for climate change impact frequency and severity of hazards …

Coastal flooding/storm surge | Inland flooding | **Wind damage** | Epidemic diseases

Return period
Years

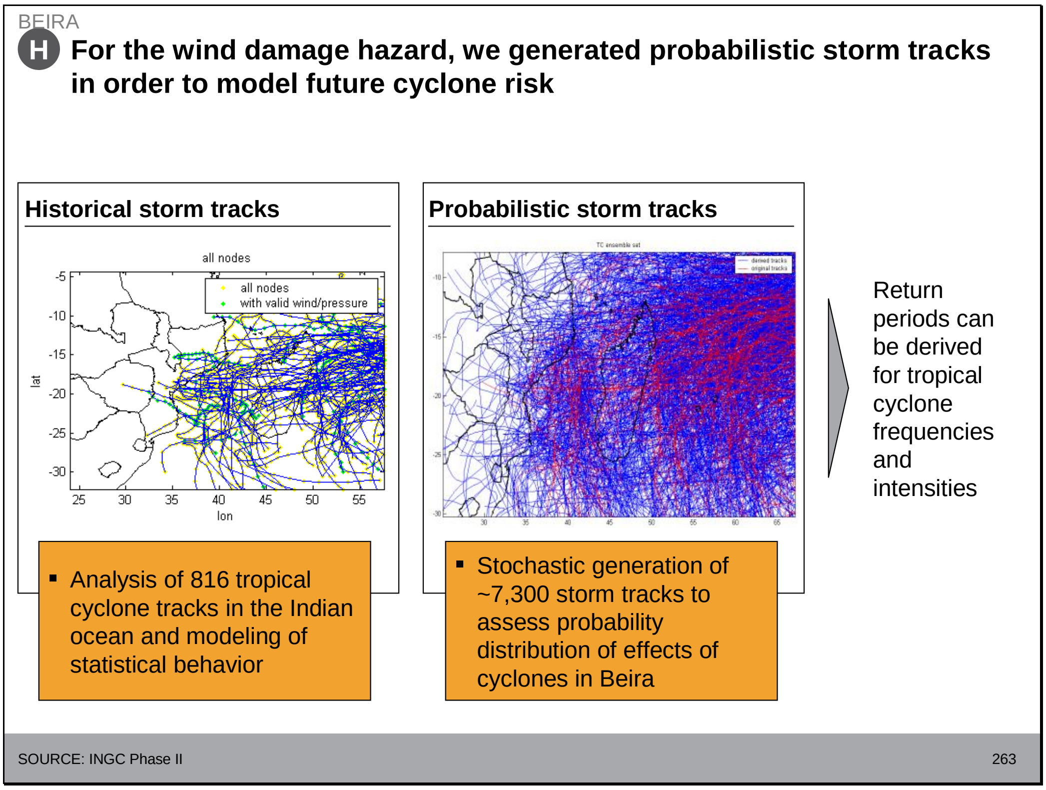
Ⓐ Storm with wind speed of 159 km/h expected every 100 years in today's climate

Ⓑ Storm with wind speed of 181 km/h expected every 100 years under high CC scenario

Wind speed
Km per hour

SOURCE: INGC Phase I report; INGC Phase II

SLIDE 264



BEIRA

H For the wind damage hazard, we generated probabilistic storm tracks in order to model future cyclone risk

Historical storm tracks

- Analysis of 816 tropical cyclone tracks in the Indian ocean and modeling of statistical behavior

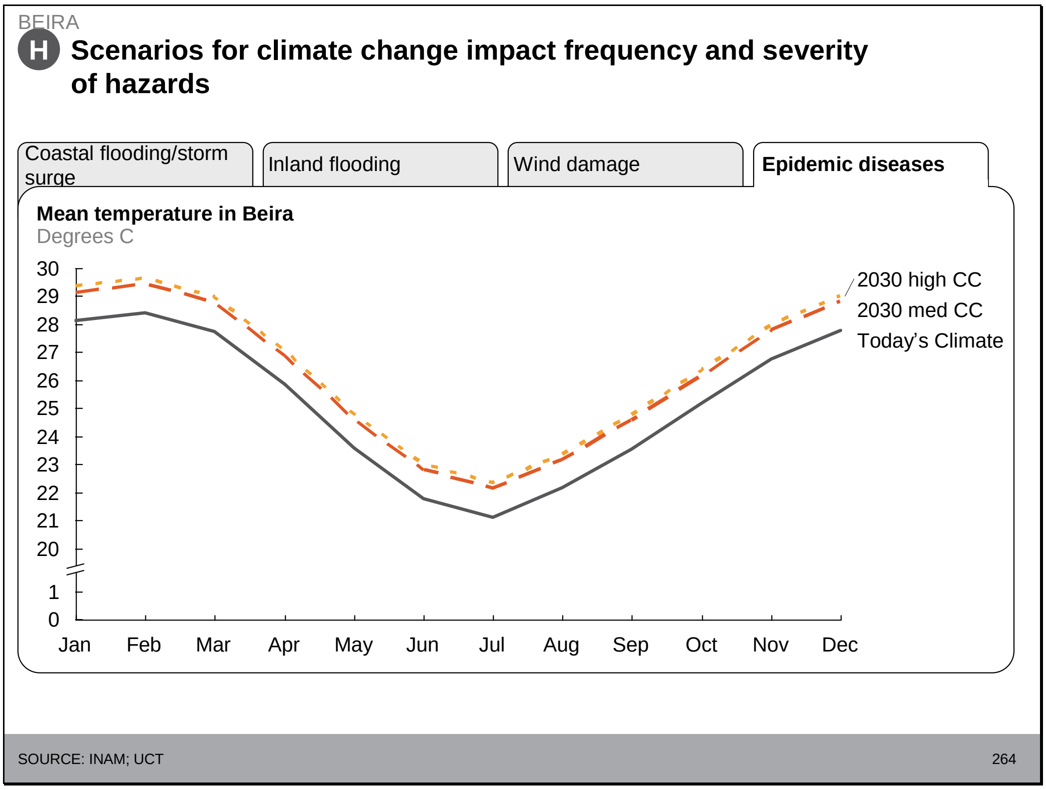
Probabilistic storm tracks

- Stochastic generation of ~7,300 storm tracks to assess probability distribution of effects of cyclones in Beira

Return periods can be derived for tropical cyclone frequencies and intensities

SOURCE: INGC Phase II

SLIDE 265



BEIRA

H Scenarios for climate change impact frequency and severity of hazards

Coastal flooding/storm surge | Inland flooding | Wind damage | **Epidemic diseases**

Mean temperature in Beira
Degrees C

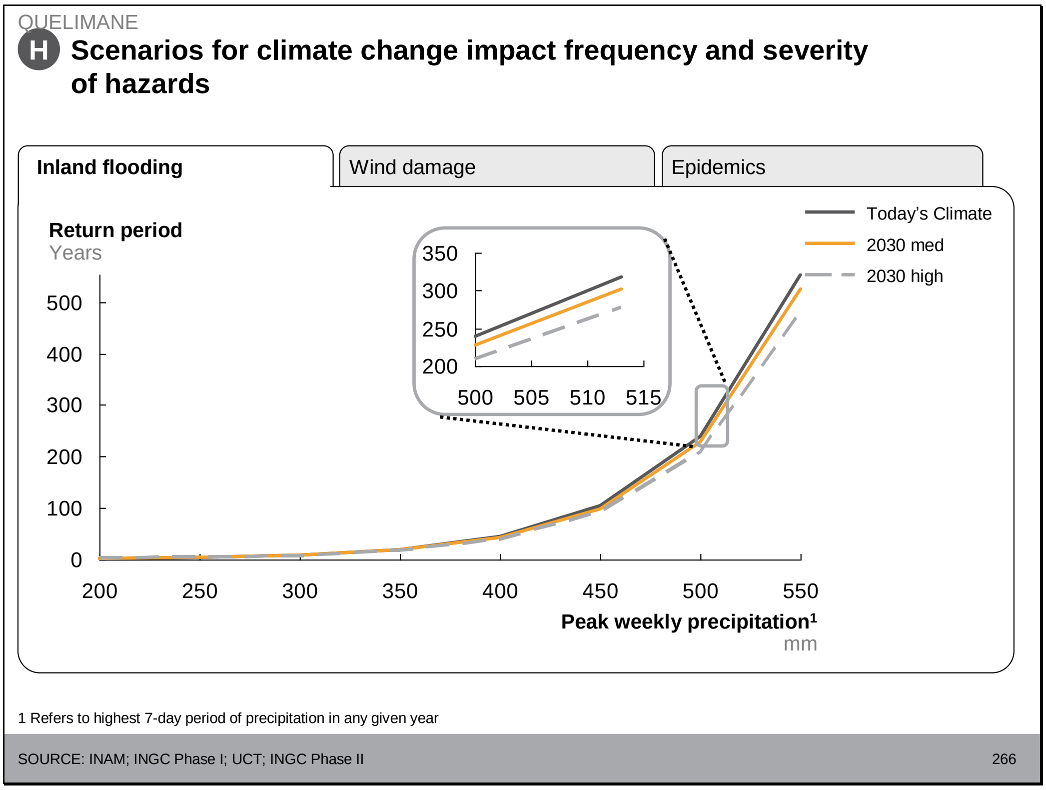
SOURCE: INAM; UCT

SLIDE 266

Contents

- Climate change scenarios
- **Hazard curves**
  - Maputo
  - Beira
  - **Quelimane**
- Vulnerability curves
- Long list of adaptation measures
- Details on best practice cities

SLIDE 267



QUELIMANE

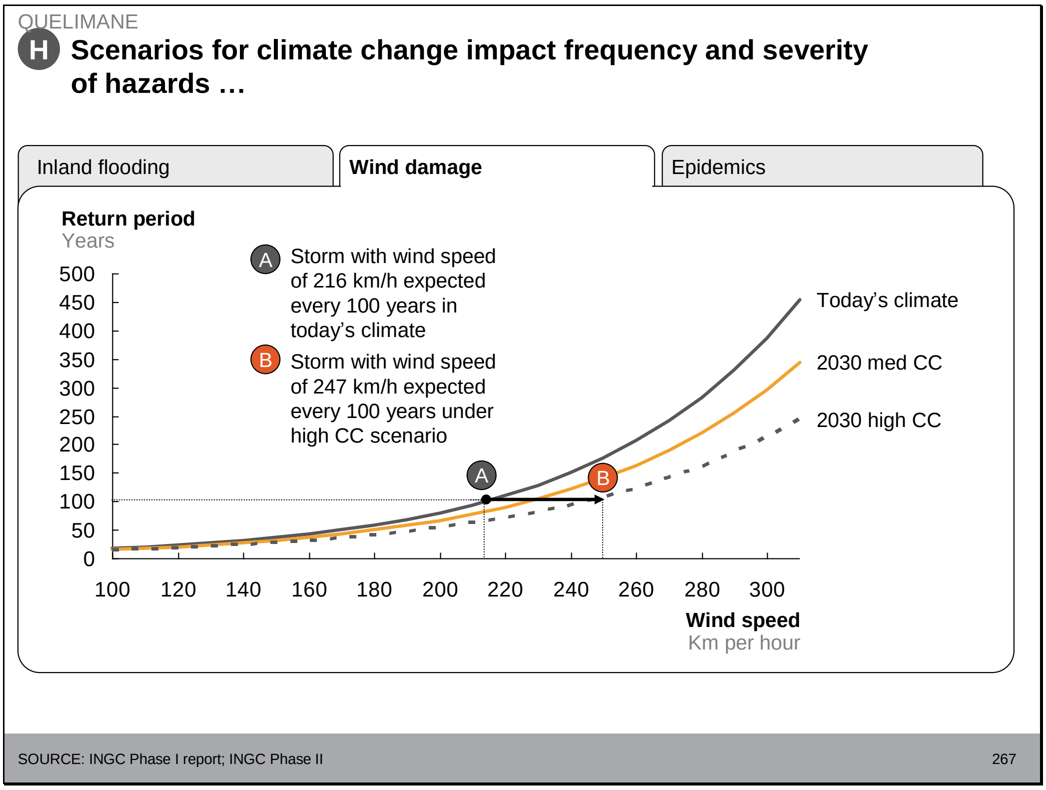
H Scenarios for climate change impact frequency and severity of hazards

Inland flooding | Wind damage | Epidemics

1 Refers to highest 7-day period of precipitation in any given year

SOURCE: INAM; INGC Phase I; UCT; INGC Phase II

SLIDE 268



QUELIMANE

H Scenarios for climate change impact frequency and severity of hazards …

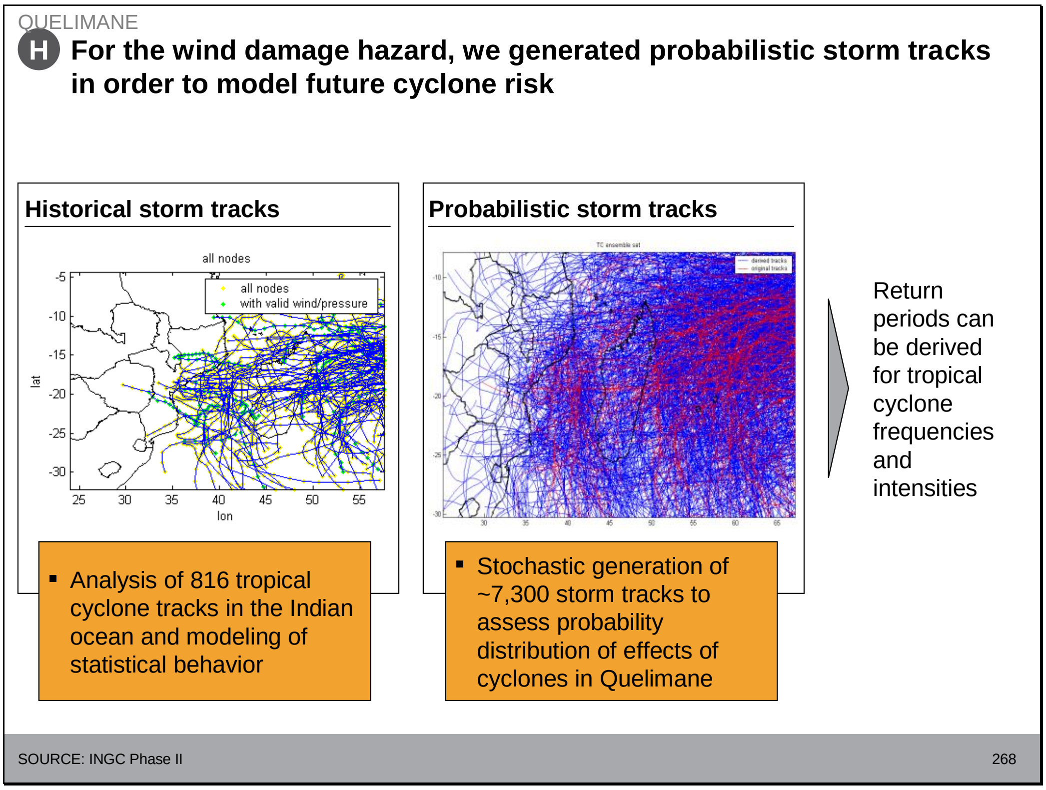
Inland flooding | **Wind damage** | Epidemics

Ⓐ Storm with wind speed of 216 km/h expected every 100 years in today's climate

Ⓑ Storm with wind speed of 247 km/h expected every 100 years under high CC scenario

SOURCE: INGC Phase I report; INGC Phase II

SLIDE 269



QUELIMANE

H For the wind damage hazard, we generated probabilistic storm tracks in order to model future cyclone risk

Historical storm tracks

- Analysis of 816 tropical cyclone tracks in the Indian ocean and modeling of statistical behavior

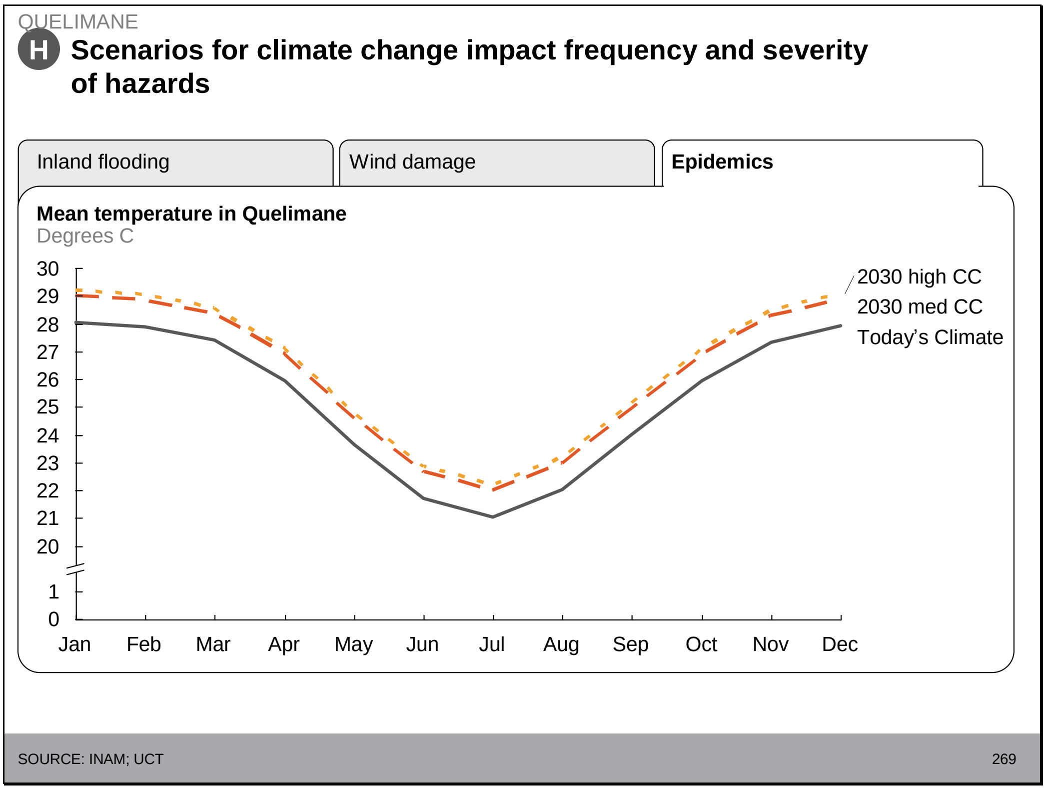
Probabilistic storm tracks

- Stochastic generation of ~7,300 storm tracks to assess probability distribution of effects of cyclones in Quelimane

Return periods can be derived for tropical cyclone frequencies and intensities

SOURCE: INGC Phase II

SLIDE 270



QUELIMANE

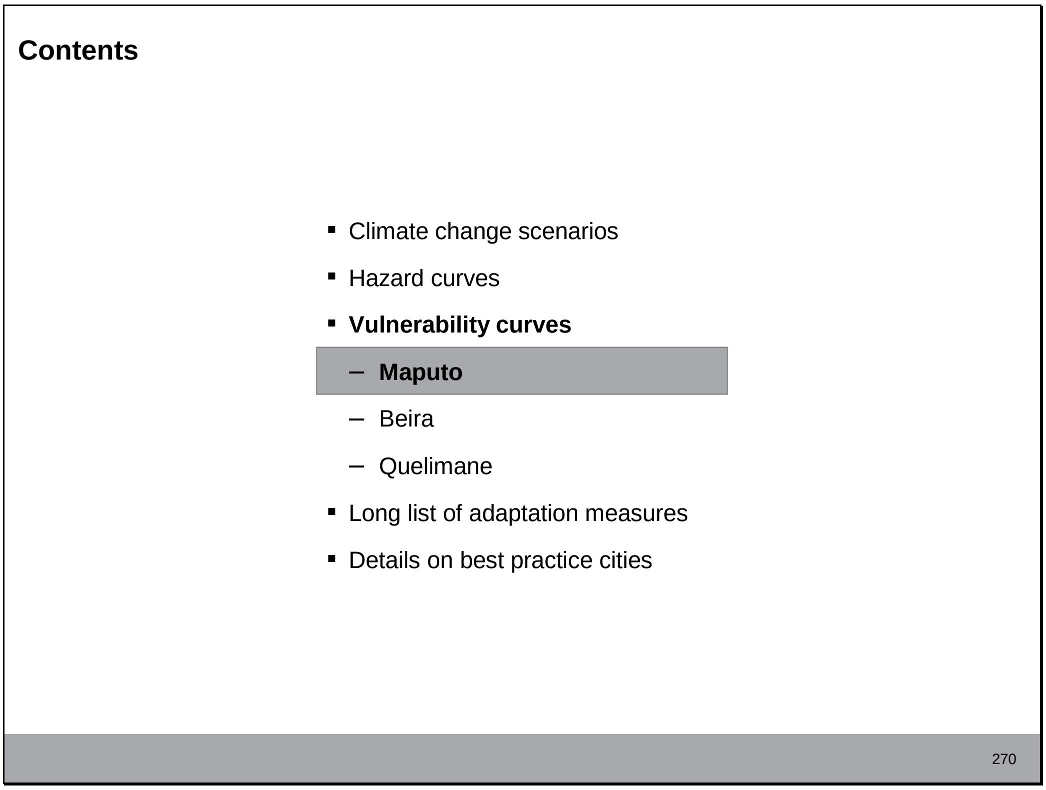
H Scenarios for climate change impact frequency and severity of hazards

Inland flooding | Wind damage | **Epidemics**

Mean temperature in Quelimane
Degrees C

SOURCE: INAM; UCT

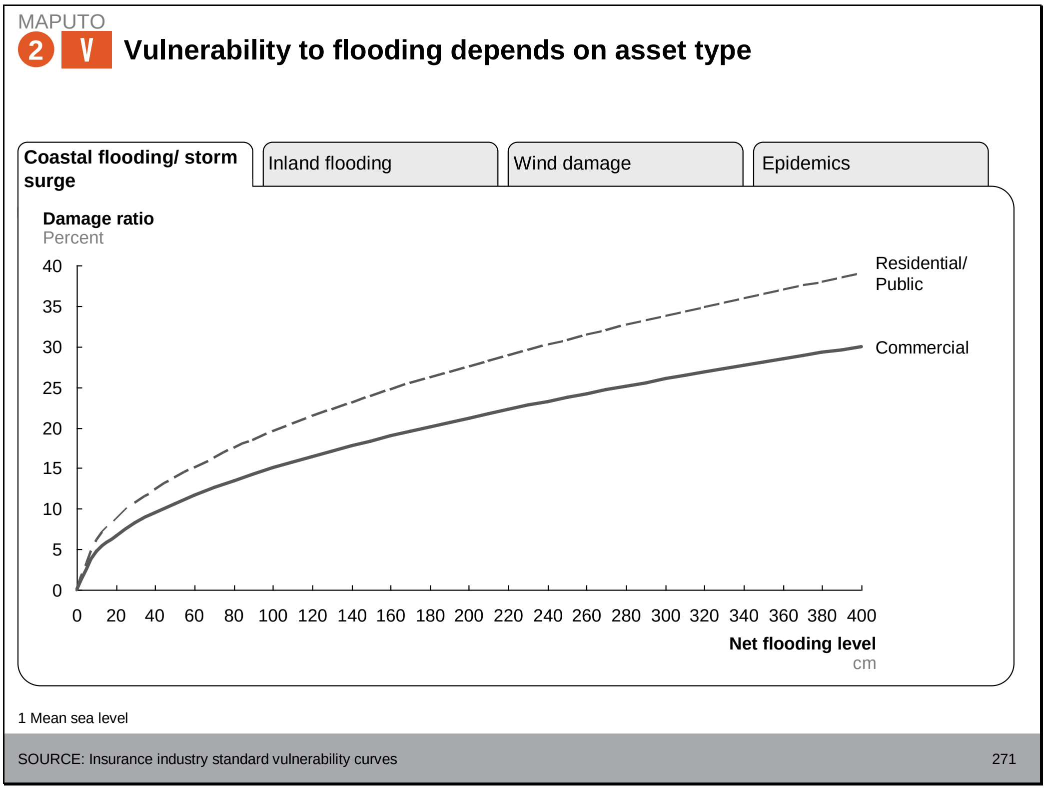
SLIDE 271



Contents

- Climate change scenarios
- Hazard curves
- **Vulnerability curves**
  - **Maputo**
  - Beira
  - Quelimane
- Long list of adaptation measures
- Details on best practice cities

SLIDE 272



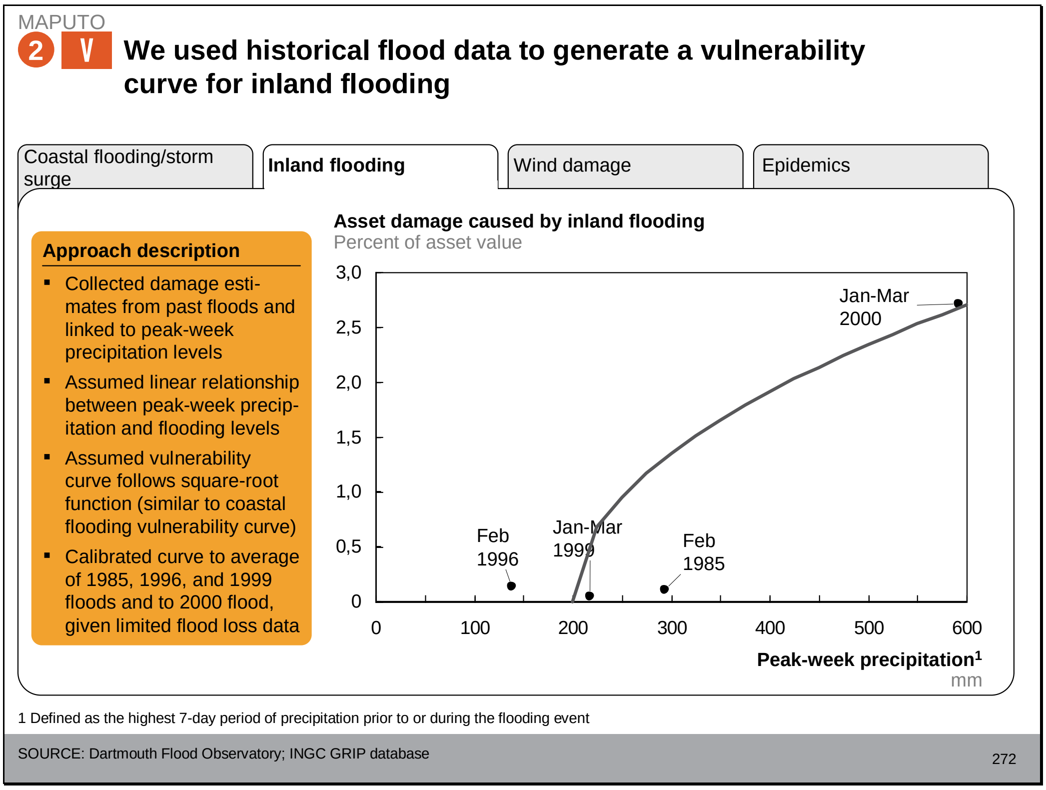
MAPUTO

2 V **Vulnerability to flooding depends on asset type**

1 Mean sea level

SOURCE: Insurance industry standard vulnerability curves

SLIDE 273



MAPUTO

2 V We used historical flood data to generate a vulnerability curve for inland flooding

Coastal flooding/storm surge | **Inland flooding** | Wind damage | Epidemics

Approach description

- Collected damage estimates from past floods and linked to peak-week precipitation levels
- Assumed linear relationship between peak-week precipitation and flooding levels
- Assumed vulnerability curve follows square-root function (similar to coastal flooding vulnerability curve)
- Calibrated curve to average of 1985, 1996, and 1999 floods and to 2000 flood, given limited flood loss data

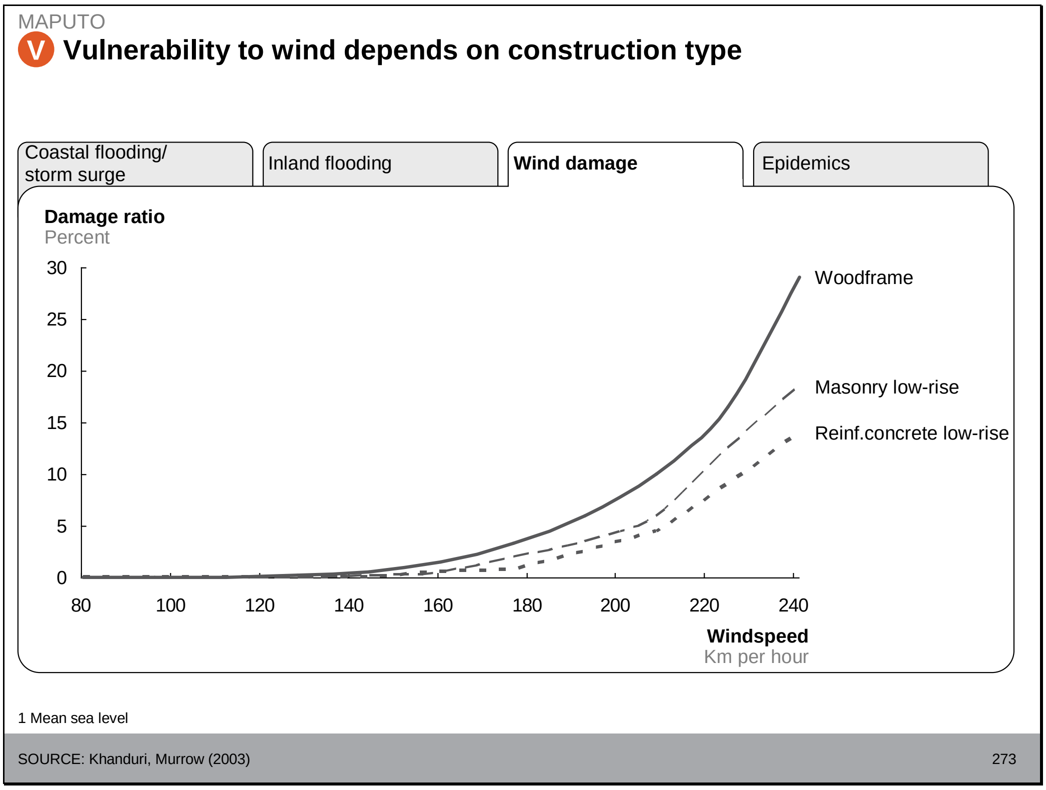
Asset damage caused by inland flooding
Percent of asset value

1 Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: Dartmouth Flood Observatory; INGC GRIP database

272

SLIDE 274



MAPUTO

V Vulnerability to wind depends on construction type

Coastal flooding/ storm surge | Inland flooding | **Wind damage** | Epidemics

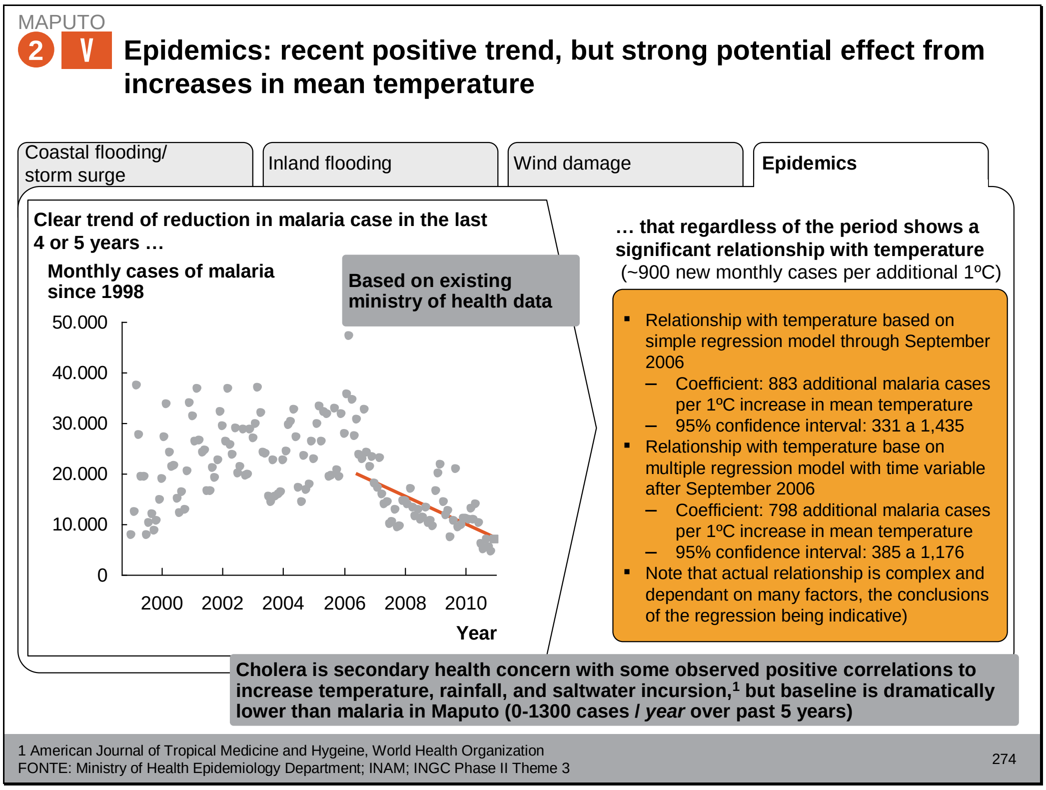
Damage ratio
Percent

1 Mean sea level

SOURCE: Khanduri, Murrow (2003)

273

SLIDE 275



MAPUTO

2 V

Epidemics: recent positive trend, but strong potential effect from increases in mean temperature

Coastal flooding/ storm surge | Inland flooding | Wind damage | **Epidemics**

Clear trend of reduction in malaria case in the last 4 or 5 years …

Monthly cases of malaria since 1998

Based on existing ministry of health data

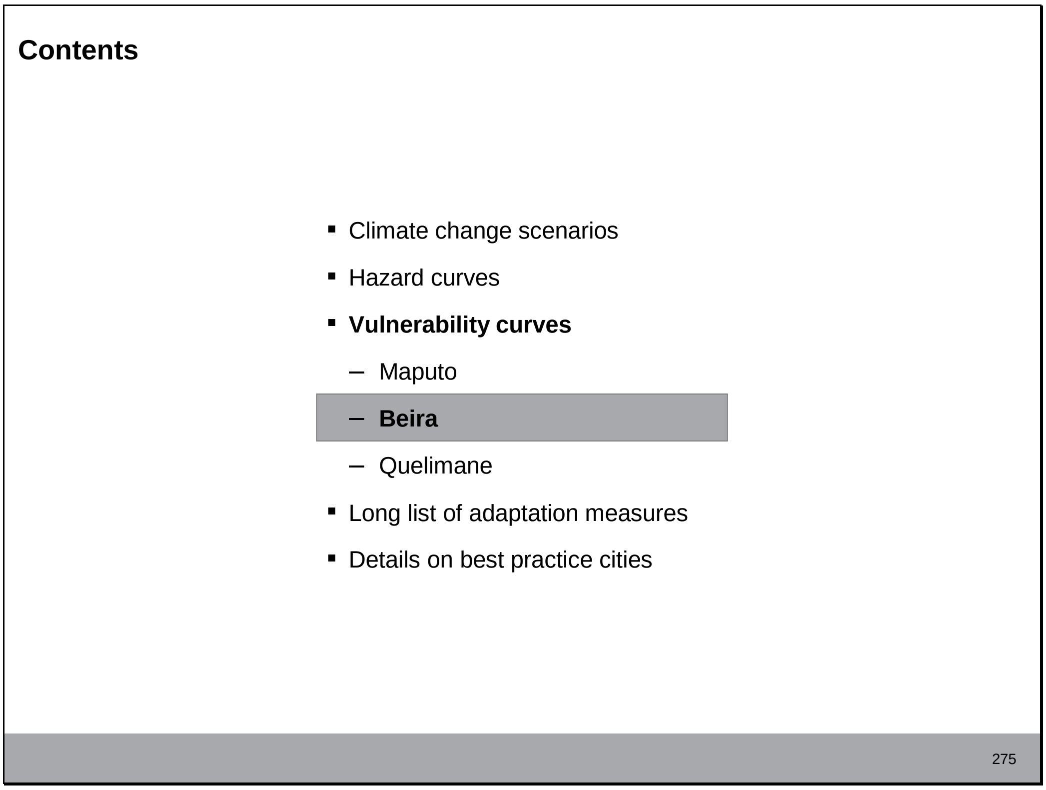
… that regardless of the period shows a significant relationship with temperature
(~900 new monthly cases per additional 1ºC)

- Relationship with temperature based on simple regression model through September 2006
  - Coefficient: 883 additional malaria cases per 1ºC increase in mean temperature
  - 95% confidence interval: 331 a 1,435
- Relationship with temperature base on multiple regression model with time variable after September 2006
  - Coefficient: 798 additional malaria cases per 1ºC increase in mean temperature
  - 95% confidence interval: 385 a 1,176
- Note that actual relationship is complex and dependant on many factors, the conclusions of the regression being indicative)

Cholera is secondary health concern with some observed positive correlations to increase temperature, rainfall, and saltwater incursion,[1] but baseline is dramatically lower than malaria in Maputo (0-1300 cases / *year* over past 5 years)

1 American Journal of Tropical Medicine and Hygeine, World Health Organization
FONTE: Ministry of Health Epidemiology Department; INAM; INGC Phase II Theme 3

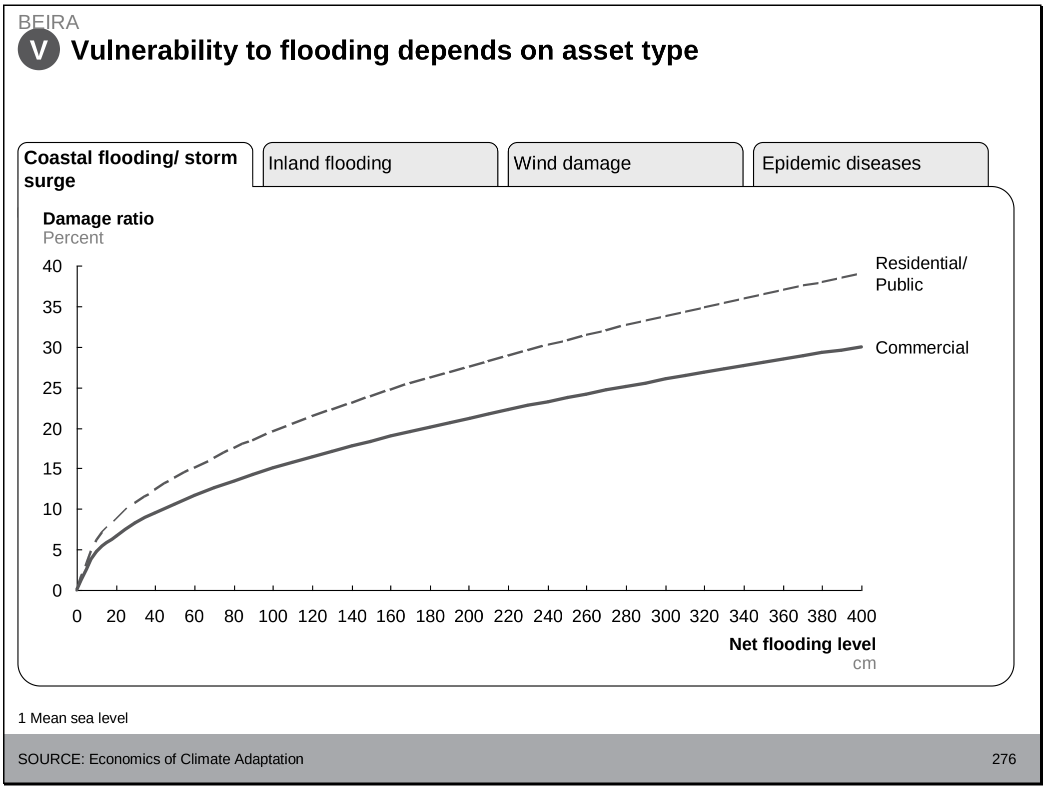
SLIDE 276



Contents

- Climate change scenarios
- Hazard curves
- **Vulnerability curves**
  - Maputo
  - **Beira**
  - Quelimane
- Long list of adaptation measures
- Details on best practice cities

SLIDE 277



BEIRA

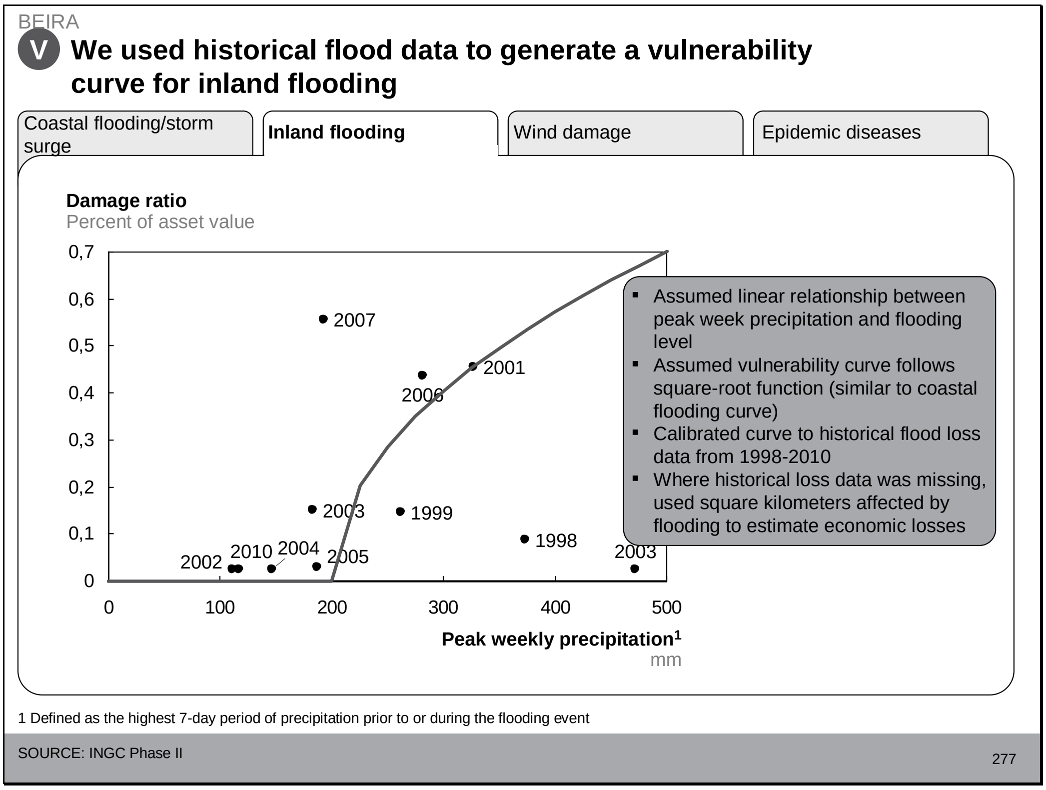
V Vulnerability to flooding depends on asset type

Coastal flooding/ storm surge | Inland flooding | Wind damage | Epidemic diseases

1 Mean sea level

SOURCE: Economics of Climate Adaptation

SLIDE 278



BEIRA

V We used historical flood data to generate a vulnerability curve for inland flooding

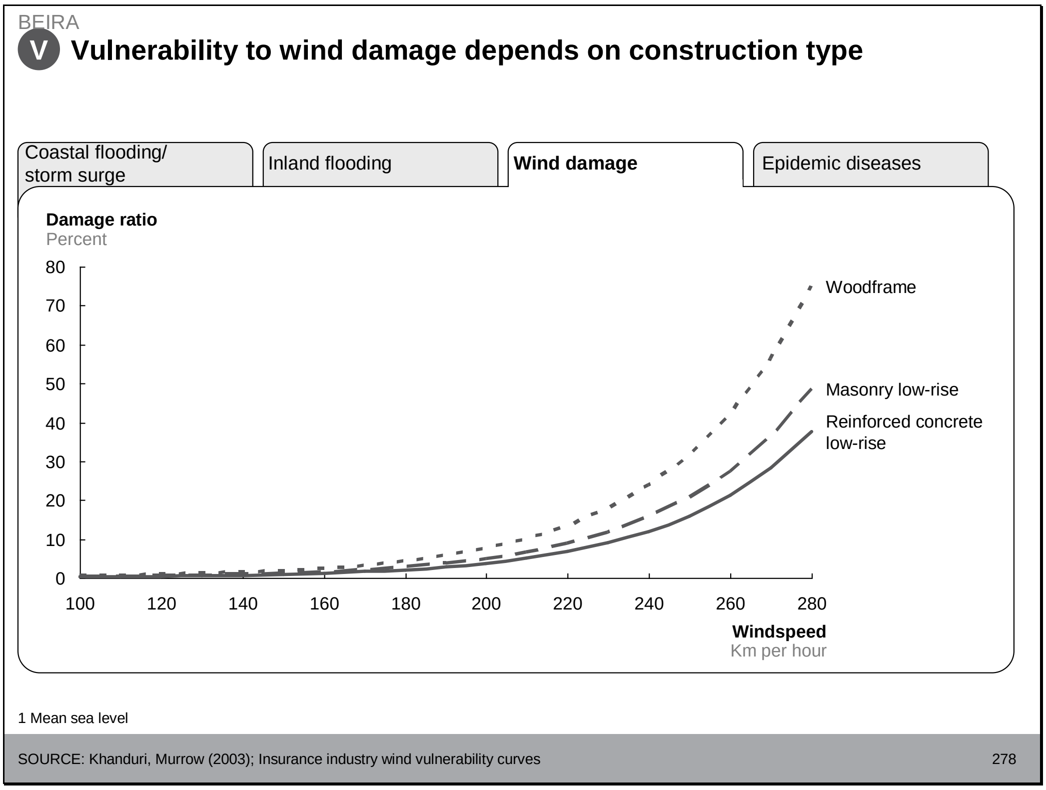
Coastal flooding/storm surge | **Inland flooding** | Wind damage | Epidemic diseases

- Assumed linear relationship between peak week precipitation and flooding level
- Assumed vulnerability curve follows square-root function (similar to coastal flooding curve)
- Calibrated curve to historical flood loss data from 1998-2010
- Where historical loss data was missing, used square kilometers affected by flooding to estimate economic losses

1 Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: INGC Phase II

SLIDE 279



BEIRA

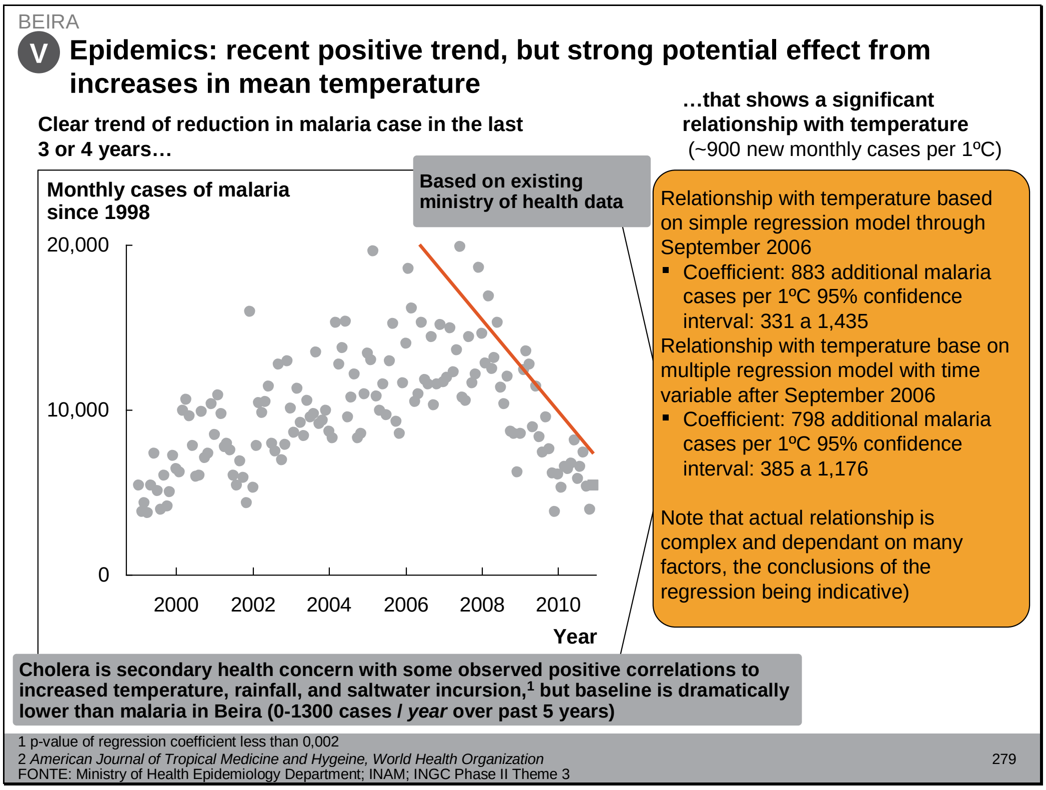
V Vulnerability to wind damage depends on construction type

Coastal flooding/ storm surge | Inland flooding | **Wind damage** | Epidemic diseases

1 Mean sea level

SOURCE: Khanduri, Murrow (2003); Insurance industry wind vulnerability curves

SLIDE 280



BEIRA

V Epidemics: recent positive trend, but strong potential effect from increases in mean temperature

Clear trend of reduction in malaria case in the last 3 or 4 years…

Based on existing ministry of health data

…that shows a significant relationship with temperature
(~900 new monthly cases per 1ºC)

Relationship with temperature based on simple regression model through September 2006

- Coefficient: 883 additional malaria cases per 1ºC 95% confidence interval: 331 a 1,435

Relationship with temperature base on multiple regression model with time variable after September 2006

- Coefficient: 798 additional malaria cases per 1ºC 95% confidence interval: 385 a 1,176

Note that actual relationship is complex and dependant on many factors, the conclusions of the regression being indicative)

Cholera is secondary health concern with some observed positive correlations to increased temperature, rainfall, and saltwater incursion,[1] but baseline is dramatically lower than malaria in Beira (0-1300 cases / *year* over past 5 years)

1 p-value of regression coefficient less than 0,002

2 *American Journal of Tropical Medicine and Hygeine, World Health Organization*

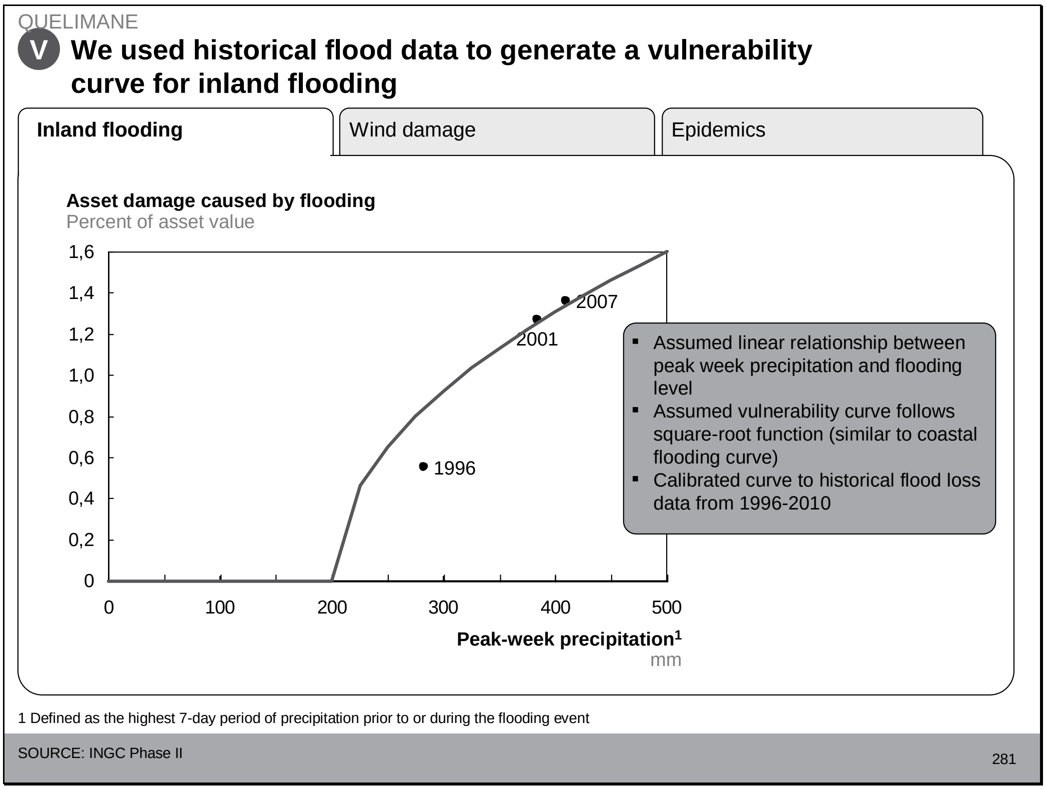
FONTE: Ministry of Health Epidemiology Department; INAM; INGC Phase II Theme 3

SLIDE 281

Contents

- Climate change scenarios
- Hazard curves
- **Vulnerability curves**
  - Maputo
  - Beira
  - **Quelimane**
- Long list of adaptation measures
- Details on best practice cities

SLIDE 282



QUELIMANE

V We used historical flood data to generate a vulnerability curve for inland flooding

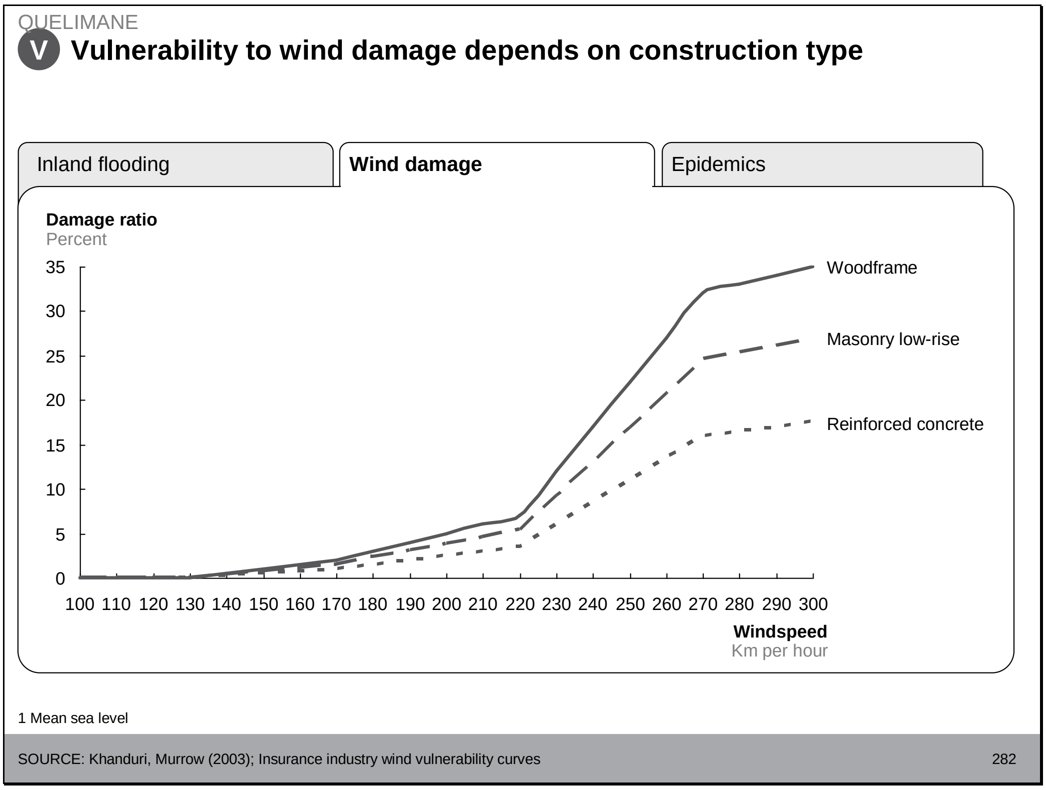
Inland flooding | Wind damage | Epidemics

- Assumed linear relationship between peak week precipitation and flooding level
- Assumed vulnerability curve follows square-root function (similar to coastal flooding curve)
- Calibrated curve to historical flood loss data from 1996-2010

1 Defined as the highest 7-day period of precipitation prior to or during the flooding event

SOURCE: INGC Phase II

SLIDE 283



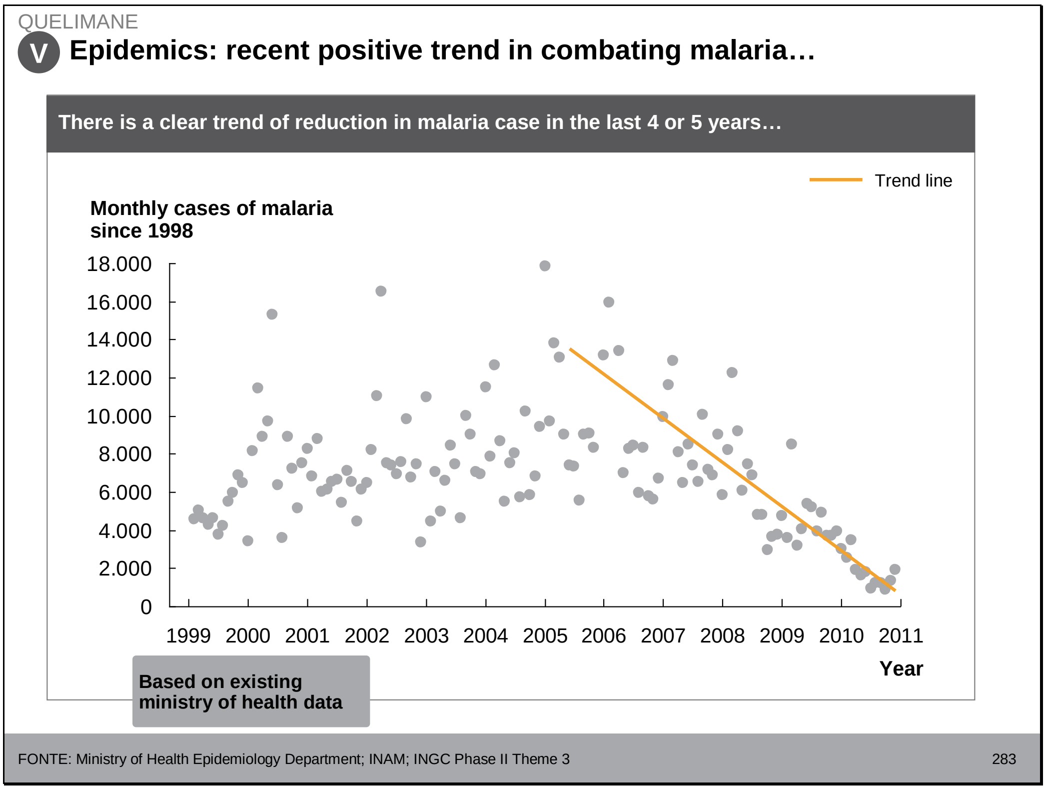
QUELIMANE

V Vulnerability to wind damage depends on construction type

1 Mean sea level

SOURCE: Khanduri, Murrow (2003); Insurance industry wind vulnerability curves

SLIDE 284



QUELIMANE

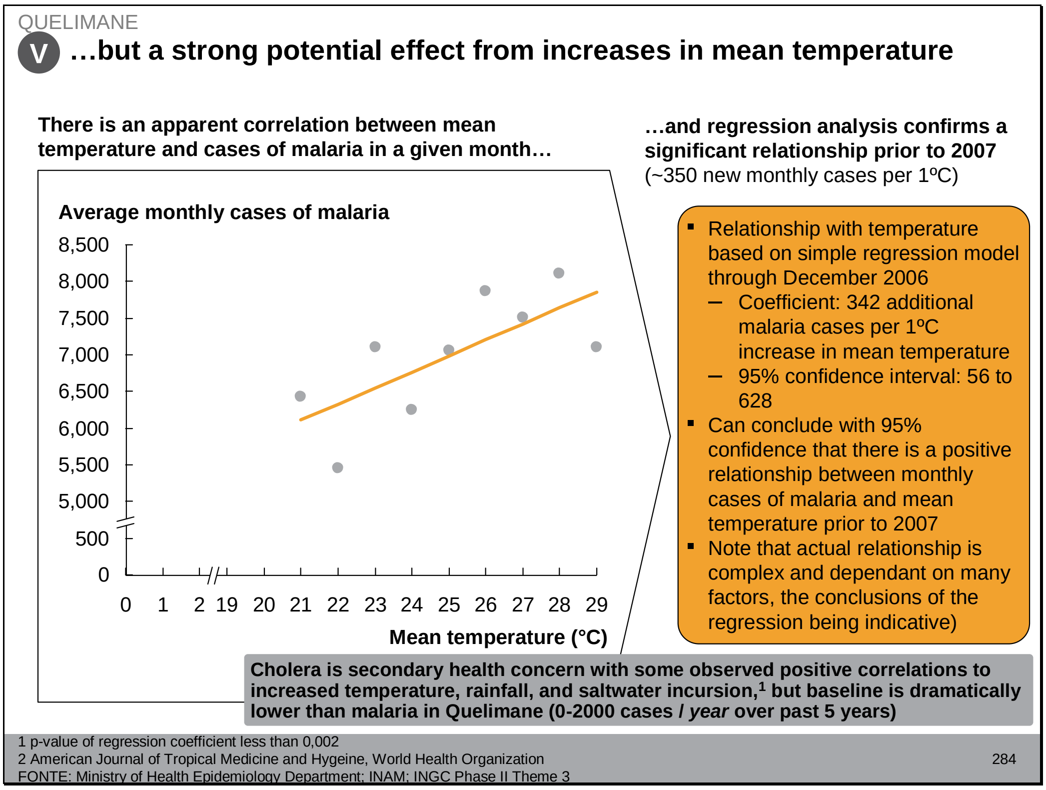
V Epidemics: recent positive trend in combating malaria…

There is a clear trend of reduction in malaria case in the last 4 or 5 years…

Based on existing ministry of health data

FONTE: Ministry of Health Epidemiology Department; INAM; INGC Phase II Theme 3

SLIDE 285



QUELIMANE

V …but a strong potential effect from increases in mean temperature

There is an apparent correlation between mean temperature and cases of malaria in a given month…

…and regression analysis confirms a significant relationship prior to 2007 (~350 new monthly cases per 1ºC)

- Relationship with temperature based on simple regression model through December 2006
  - Coefficient: 342 additional malaria cases per 1ºC increase in mean temperature
  - 95% confidence interval: 56 to 628
- Can conclude with 95% confidence that there is a positive relationship between monthly cases of malaria and mean temperature prior to 2007
- Note that actual relationship is complex and dependant on many factors, the conclusions of the regression being indicative)

Cholera is secondary health concern with some observed positive correlations to increased temperature, rainfall, and saltwater incursion,[1] but baseline is dramatically lower than malaria in Quelimane (0-2000 cases / *year* over past 5 years)

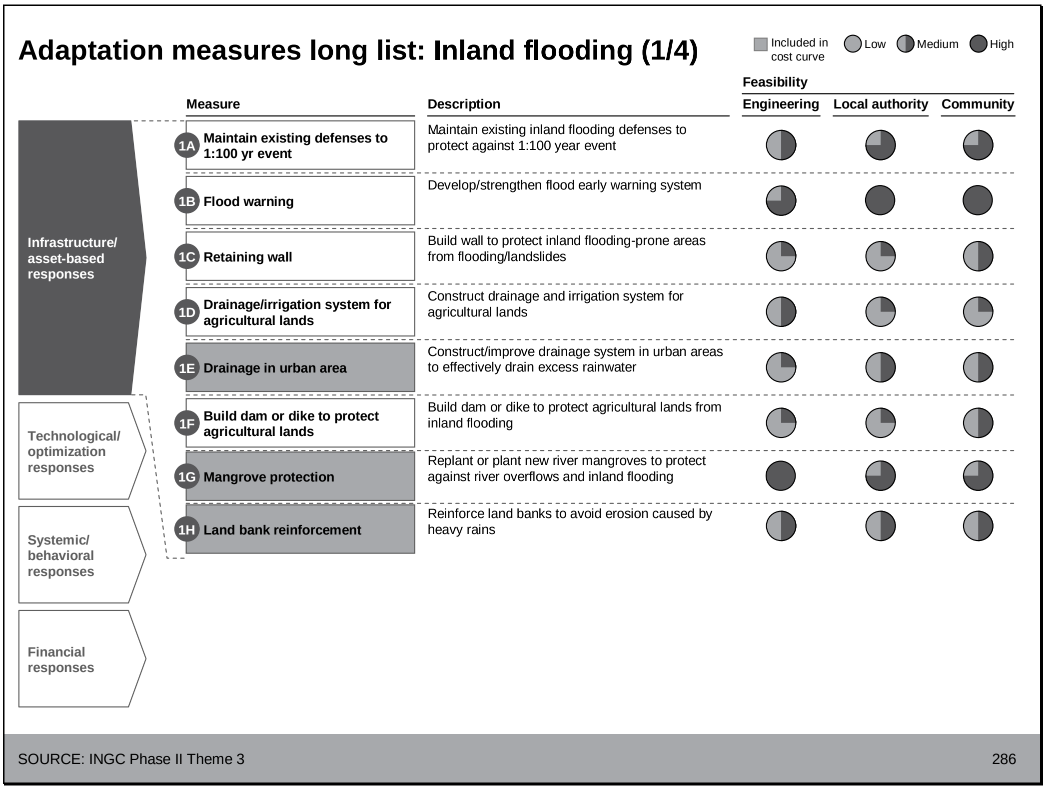
1 p-value of regression coefficient less than 0,002
2 American Journal of Tropical Medicine and Hygeine, World Health Organization
FONTE: Ministry of Health Epidemiology Department; INAM; INGC Phase II Theme 3

SLIDE 286

Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- **Long list of adaptation measures**
- Details on best practice cities

SLIDE 287



Adaptation measures long list: Inland flooding (1/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset-based responses

Technological/ optimization responses

Systemic/ behavioral responses

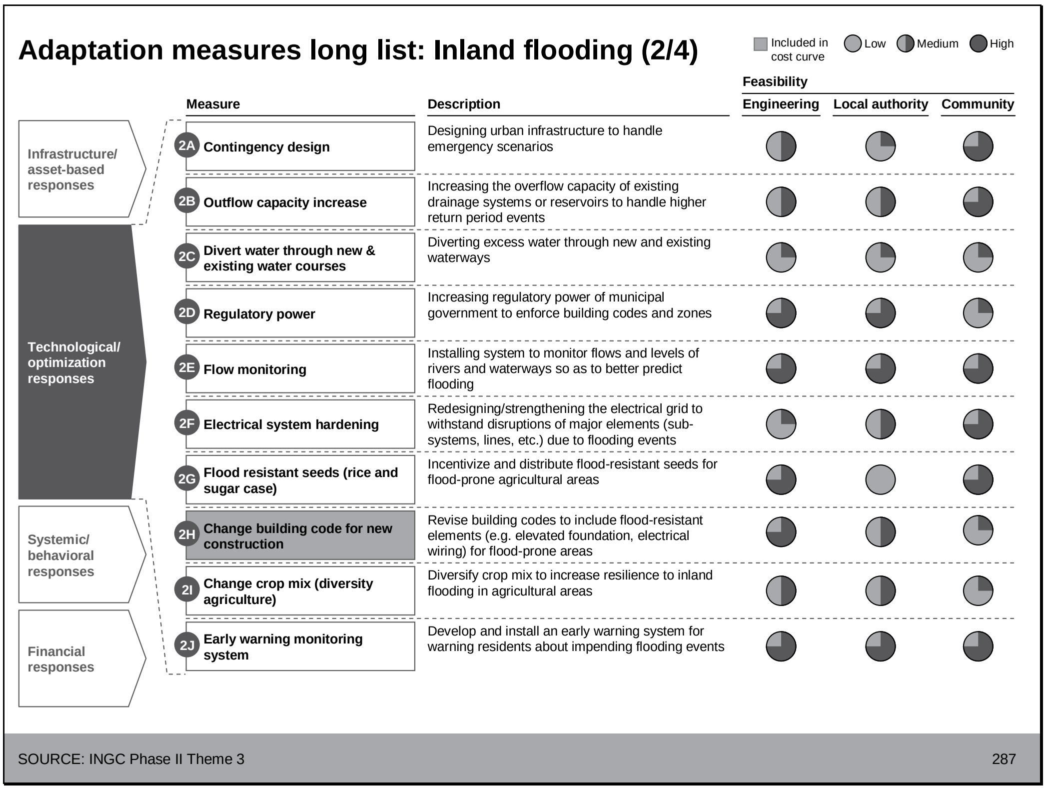
Financial responses

Measure	Description	Feasibility Engineering	Local authority	Community
1A **Maintain existing defenses to 1:100 yr event**	Maintain existing inland flooding defenses to protect against 1:100 year event	◑	◕	◕
1B **Flood warning**	Develop/strengthen flood early warning system	◕	●	●
1C **Retaining wall**	Build wall to protect inland flooding-prone areas from flooding/landslides	◔	◔	◑
1D **Drainage/irrigation system for agricultural lands**	Construct drainage and irrigation system for agricultural lands	◑	◔	◔
1E **Drainage in urban area** ▨	Construct/improve drainage system in urban areas to effectively drain excess rainwater	◔	◑	◑
1F **Build dam or dike to protect agricultural lands**	Build dam or dike to protect agricultural lands from inland flooding	◔	◔	◑
1G **Mangrove protection** ▨	Replant or plant new river mangroves to protect against river overflows and inland flooding	●	◕	◕
1H **Land bank reinforcement** ▨	Reinforce land banks to avoid erosion caused by heavy rains	◑	◑	◑

SOURCE: INGC Phase II Theme 3

286

SLIDE 288



Adaptation measures long list: Inland flooding (2/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset-based responses

Technological/ optimization responses

Systemic/ behavioral responses

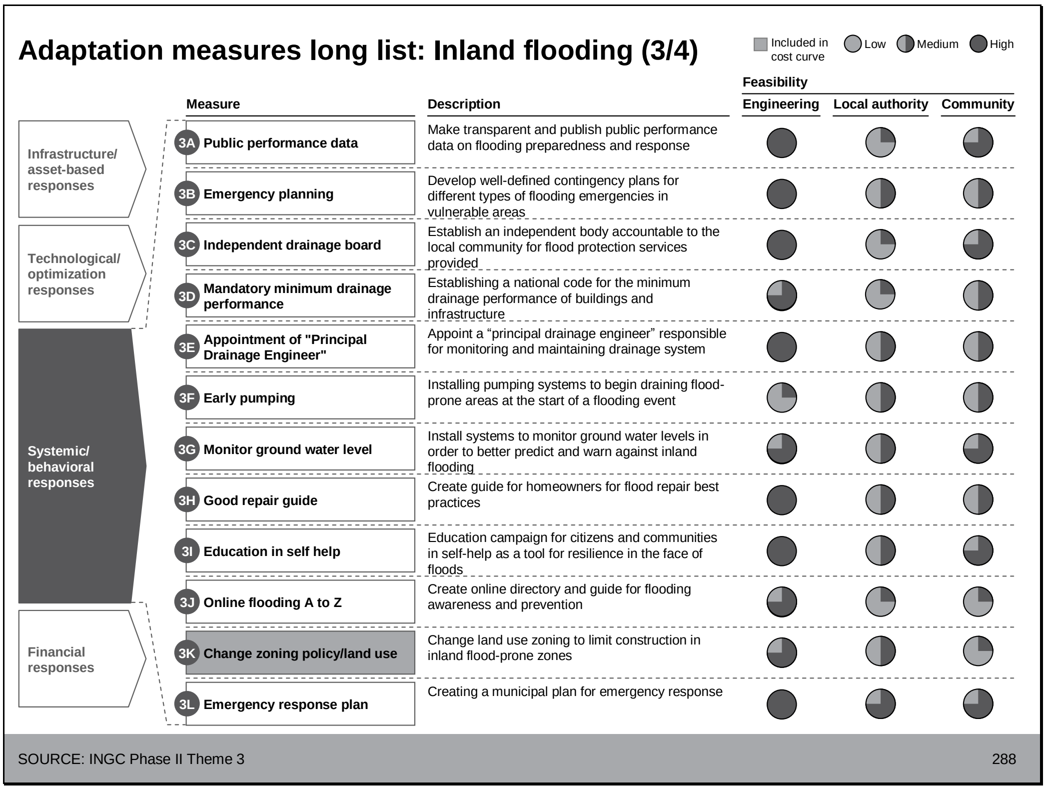
Financial responses

Measure	Description	Feasibility Engineering	Local authority	Community
2A **Contingency design**	Designing urban infrastructure to handle emergency scenarios	◑	◔	◕
2B **Outflow capacity increase**	Increasing the overflow capacity of existing drainage systems or reservoirs to handle higher return period events	◑	◑	◕
2C **Divert water through new & existing water courses**	Diverting excess water through new and existing waterways	◔	◔	◔
2D **Regulatory power**	Increasing regulatory power of municipal government to enforce building codes and zones	◕	◕	◔
2E **Flow monitoring**	Installing system to monitor flows and levels of rivers and waterways so as to better predict flooding	◕	◕	◕
2F **Electrical system hardening**	Redesigning/strengthening the electrical grid to withstand disruptions of major elements (sub-systems, lines, etc.) due to flooding events	◔	◑	◕
2G **Flood resistant seeds (rice and sugar case)**	Incentivize and distribute flood-resistant seeds for flood-prone agricultural areas	◕	○	◕
2H **Change building code for new construction** ▨	Revise building codes to include flood-resistant elements (e.g. elevated foundation, electrical wiring) for flood-prone areas	◕	◑	◔
2I **Change crop mix (diversity agriculture)**	Diversify crop mix to increase resilience to inland flooding in agricultural areas	◑	◑	◔
2J **Early warning monitoring system**	Develop and install an early warning system for warning residents about impending flooding events	◕	◕	◕

SOURCE: INGC Phase II Theme 3

287

SLIDE 289



Adaptation measures long list: Inland flooding (3/4)

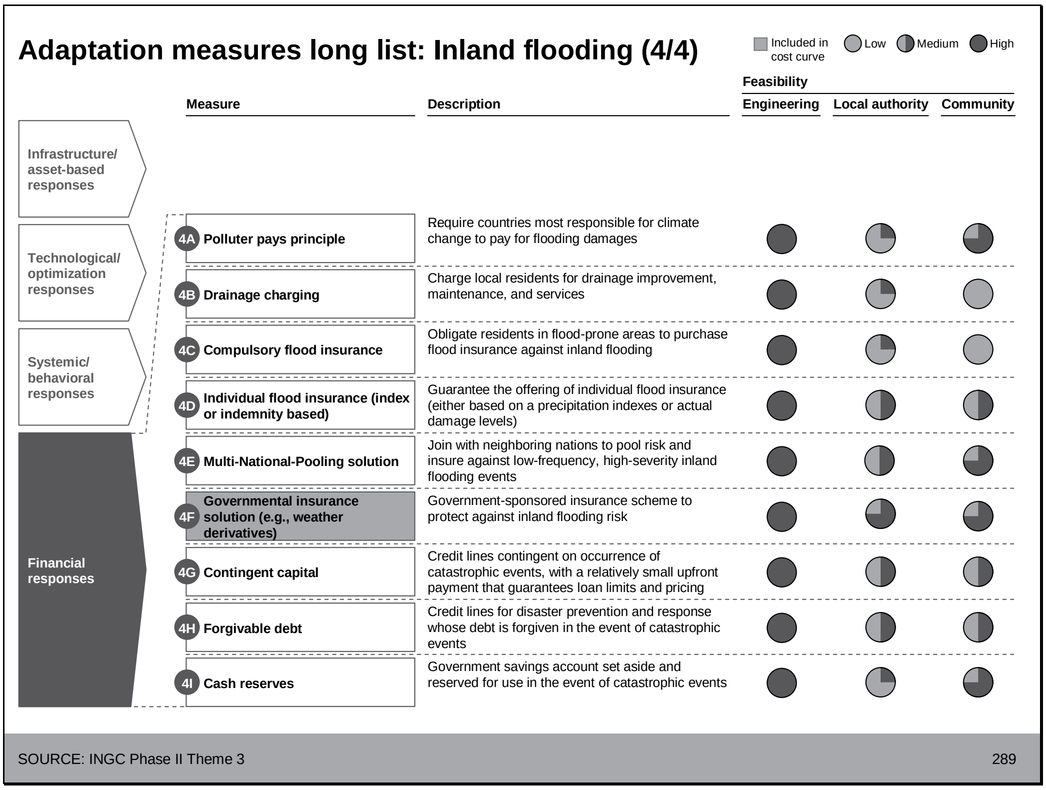
▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset-based responses
Technological/ optimization responses
Systemic/ behavioral responses
Financial responses

Measure	Description	Feasibility Engineering	Local authority	Community
3A **Public performance data**	Make transparent and publish public performance data on flooding preparedness and response	●	◔	◕
3B **Emergency planning**	Develop well-defined contingency plans for different types of flooding emergencies in vulnerable areas	●	◑	◑
3C **Independent drainage board**	Establish an independent body accountable to the local community for flood protection services provided	●	◔	◕
3D **Mandatory minimum drainage performance**	Establishing a national code for the minimum drainage performance of buildings and infrastructure	◕	◔	◑
3E **Appointment of "Principal Drainage Engineer"**	Appoint a "principal drainage engineer" responsible for monitoring and maintaining drainage system	●	◑	◑
3F **Early pumping**	Installing pumping systems to begin draining flood-prone areas at the start of a flooding event	◔	◑	◑
3G **Monitor ground water level**	Install systems to monitor ground water levels in order to better predict and warn against inland flooding	◕	◑	◕
3H **Good repair guide**	Create guide for homeowners for flood repair best practices	●	◑	◑
3I **Education in self help**	Education campaign for citizens and communities in self-help as a tool for resilience in the face of floods	●	◑	◕
3J **Online flooding A to Z**	Create online directory and guide for flooding awareness and prevention	◕	◔	◔
▨ 3K **Change zoning policy/land use**	Change land use zoning to limit construction in inland flood-prone zones	◕	◑	◔
3L **Emergency response plan**	Creating a municipal plan for emergency response	●	◕	◕

SOURCE: INGC Phase II Theme 3

SLIDE 290



Adaptation measures long list: Inland flooding (4/4)

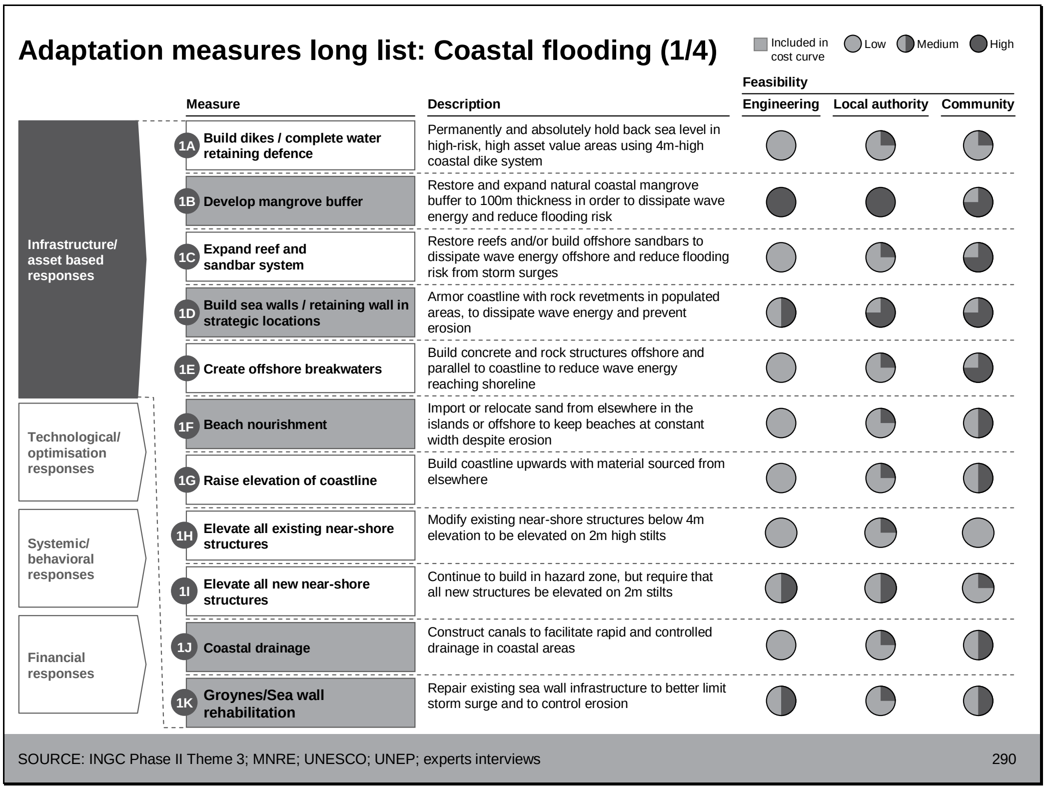
▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset-based responses
Technological/ optimization responses
Systemic/ behavioral responses
Financial responses

Measure	Description	Feasibility Engineering	Local authority	Community
4A **Polluter pays principle**	Require countries most responsible for climate change to pay for flooding damages	●	◔	◕
4B **Drainage charging**	Charge local residents for drainage improvement, maintenance, and services	●	◔	○
4C **Compulsory flood insurance**	Obligate residents in flood-prone areas to purchase flood insurance against inland flooding	●	◔	○
4D **Individual flood insurance (index or indemnity based)**	Guarantee the offering of individual flood insurance (either based on a precipitation indexes or actual damage levels)	●	◑	◑
4E **Multi-National-Pooling solution**	Join with neighboring nations to pool risk and insure against low-frequency, high-severity inland flooding events	●	◑	◕
▨ 4F **Governmental insurance solution (e.g., weather derivatives)**	Government-sponsored insurance scheme to protect against inland flooding risk	●	◕	◕
4G **Contingent capital**	Credit lines contingent on occurrence of catastrophic events, with a relatively small upfront payment that guarantees loan limits and pricing	●	◑	◑
4H **Forgivable debt**	Credit lines for disaster prevention and response whose debt is forgiven in the event of catastrophic events	●	◑	◑
4I **Cash reserves**	Government savings account set aside and reserved for use in the event of catastrophic events	●	◔	◕

SOURCE: INGC Phase II Theme 3

SLIDE 291



Adaptation measures long list: Coastal flooding (1/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

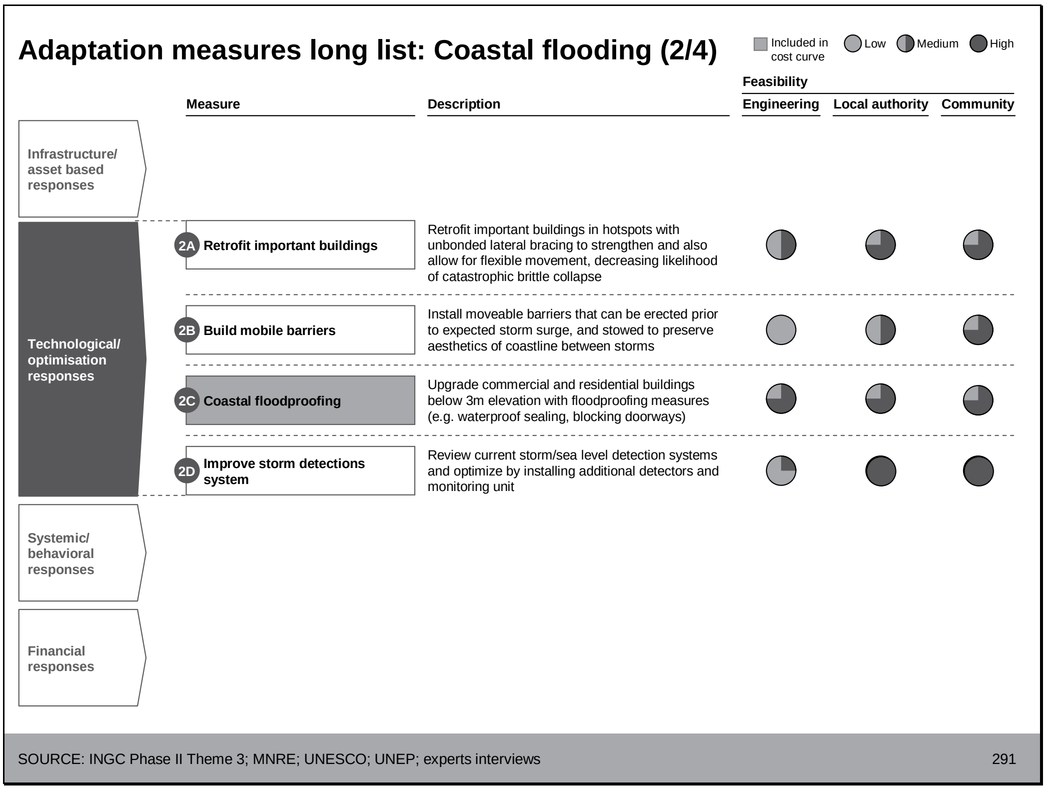
Infrastructure/ asset based responses
Technological/ optimisation responses
Systemic/ behavioral responses
Financial responses

	Measure	Description	Feasibility Engineering	Local authority	Community
1A	**Build dikes / complete water retaining defence**	Permanently and absolutely hold back sea level in high-risk, high asset value areas using 4m-high coastal dike system	○	◔	◔
1B	▨ **Develop mangrove buffer**	Restore and expand natural coastal mangrove buffer to 100m thickness in order to dissipate wave energy and reduce flooding risk	●	●	◕
1C	**Expand reef and sandbar system**	Restore reefs and/or build offshore sandbars to dissipate wave energy offshore and reduce flooding risk from storm surges	○	◔	◕
1D	▨ **Build sea walls / retaining wall in strategic locations**	Armor coastline with rock revetments in populated areas, to dissipate wave energy and prevent erosion	◑	◕	◕
1E	**Create offshore breakwaters**	Build concrete and rock structures offshore and parallel to coastline to reduce wave energy reaching shoreline	○	◔	◕
1F	▨ **Beach nourishment**	Import or relocate sand from elsewhere in the islands or offshore to keep beaches at constant width despite erosion	○	◔	◑
1G	**Raise elevation of coastline**	Build coastline upwards with material sourced from elsewhere	○	◔	◑
1H	**Elevate all existing near-shore structures**	Modify existing near-shore structures below 4m elevation to be elevated on 2m high stilts	○	◔	○
1I	**Elevate all new near-shore structures**	Continue to build in hazard zone, but require that all new structures be elevated on 2m stilts	◑	◑	◔
1J	▨ **Coastal drainage**	Construct canals to facilitate rapid and controlled drainage in coastal areas	○	◔	◑
1K	▨ **Groynes/Sea wall rehabilitation**	Repair existing sea wall infrastructure to better limit storm surge and to control erosion	◑	◔	◑

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

290

SLIDE 292



Adaptation measures long list: Coastal flooding (2/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

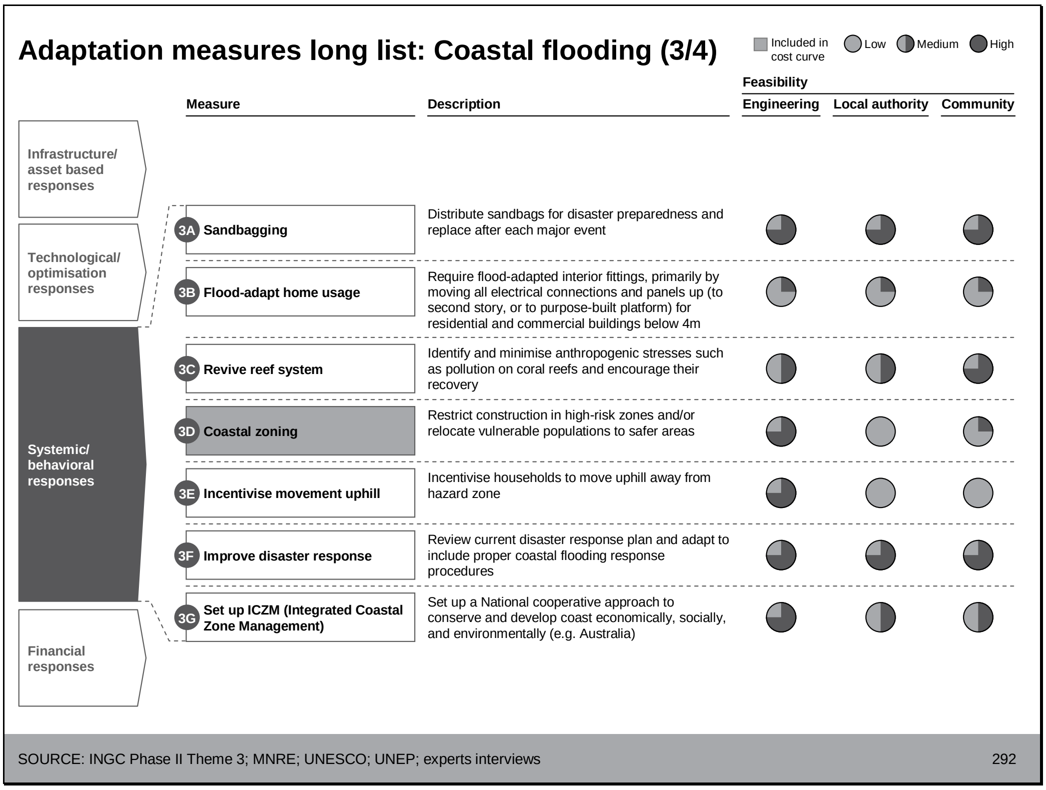
Infrastructure/ asset based responses
Technological/ optimisation responses
Systemic/ behavioral responses
Financial responses

	Measure	Description	Feasibility Engineering	Local authority	Community
2A	**Retrofit important buildings**	Retrofit important buildings in hotspots with unbonded lateral bracing to strengthen and also allow for flexible movement, decreasing likelihood of catastrophic brittle collapse	◑	◕	◕
2B	**Build mobile barriers**	Install moveable barriers that can be erected prior to expected storm surge, and stowed to preserve aesthetics of coastline between storms	○	◑	◕
2C	▨ **Coastal floodproofing**	Upgrade commercial and residential buildings below 3m elevation with floodproofing measures (e.g. waterproof sealing, blocking doorways)	◕	◕	◕
2D	**Improve storm detections system**	Review current storm/sea level detection systems and optimize by installing additional detectors and monitoring unit	◔	●	●

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

291

SLIDE 293



Adaptation measures long list: Coastal flooding (3/4)

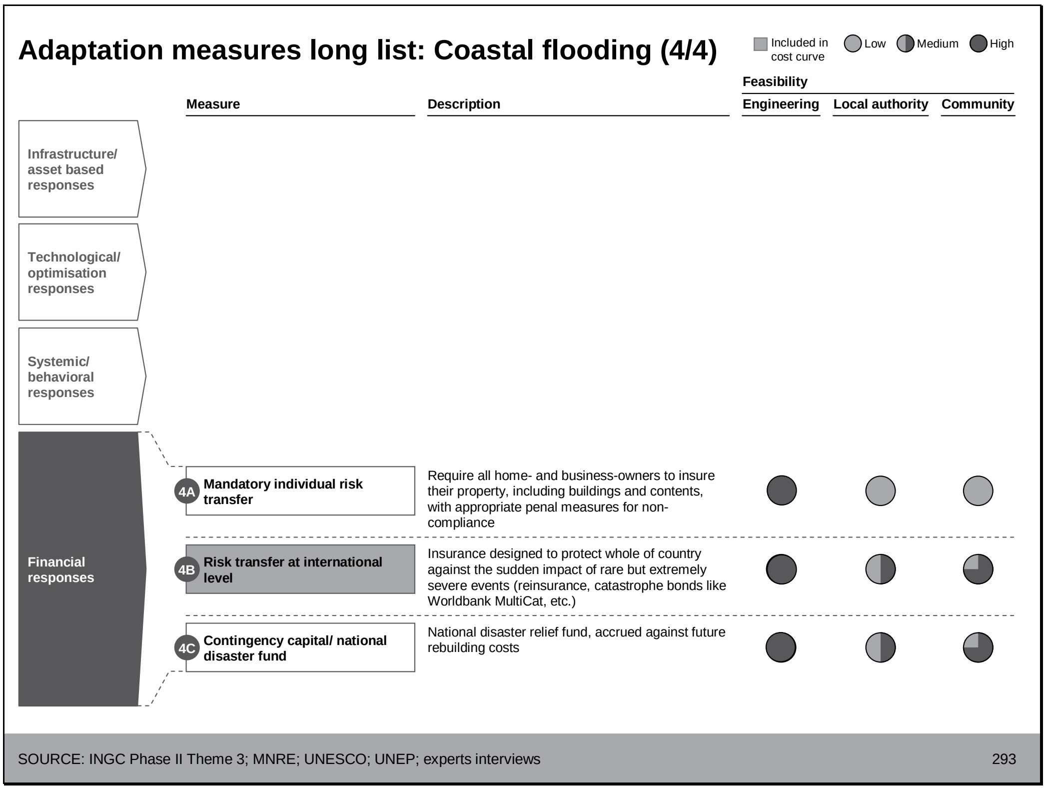
▨ Included in cost curve ○ Low ◑ Medium ● High

- Infrastructure/ asset based responses
- Technological/ optimisation responses
- **Systemic/ behavioral responses**
- Financial responses

Measure	Description	Feasibility Engineering	Feasibility Local authority	Feasibility Community
3A Sandbagging	Distribute sandbags for disaster preparedness and replace after each major event	◕	◕	◕
3B Flood-adapt home usage	Require flood-adapted interior fittings, primarily by moving all electrical connections and panels up (to second story, or to purpose-built platform) for residential and commercial buildings below 4m	◔	◔	◔
3C Revive reef system	Identify and minimise anthropogenic stresses such as pollution on coral reefs and encourage their recovery	◑	◑	◕
▨ **3D Coastal zoning**	Restrict construction in high-risk zones and/or relocate vulnerable populations to safer areas	◕	○	◔
3E Incentivise movement uphill	Incentivise households to move uphill away from hazard zone	◕	○	○
3F Improve disaster response	Review current disaster response plan and adapt to include proper coastal flooding response procedures	◕	◕	◕
3G Set up ICZM (Integrated Coastal Zone Management)	Set up a National cooperative approach to conserve and develop coast economically, socially, and environmentally (e.g. Australia)	◕	◑	◑

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 294



Adaptation measures long list: Coastal flooding (4/4)

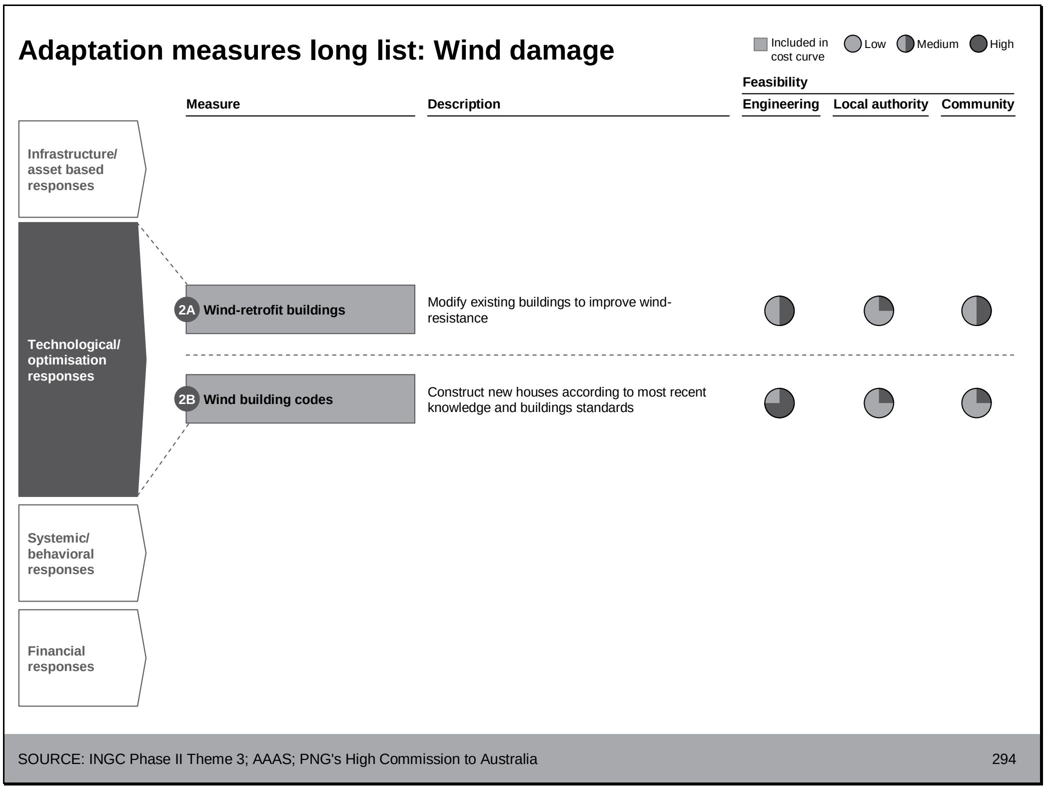
▨ Included in cost curve ○ Low ◑ Medium ● High

- Infrastructure/ asset based responses
- Technological/ optimisation responses
- Systemic/ behavioral responses
- **Financial responses**

Measure	Description	Feasibility Engineering	Feasibility Local authority	Feasibility Community
4A Mandatory individual risk transfer	Require all home- and business-owners to insure their property, including buildings and contents, with appropriate penal measures for non-compliance	●	○	○
▨ **4B Risk transfer at international level**	Insurance designed to protect whole of country against the sudden impact of rare but extremely severe events (reinsurance, catastrophe bonds like Worldbank MultiCat, etc.)	●	◑	◕
4C Contingency capital/ national disaster fund	National disaster relief fund, accrued against future rebuilding costs	●	◑	◕

SOURCE: INGC Phase II Theme 3; MNRE; UNESCO; UNEP; experts interviews

SLIDE 295



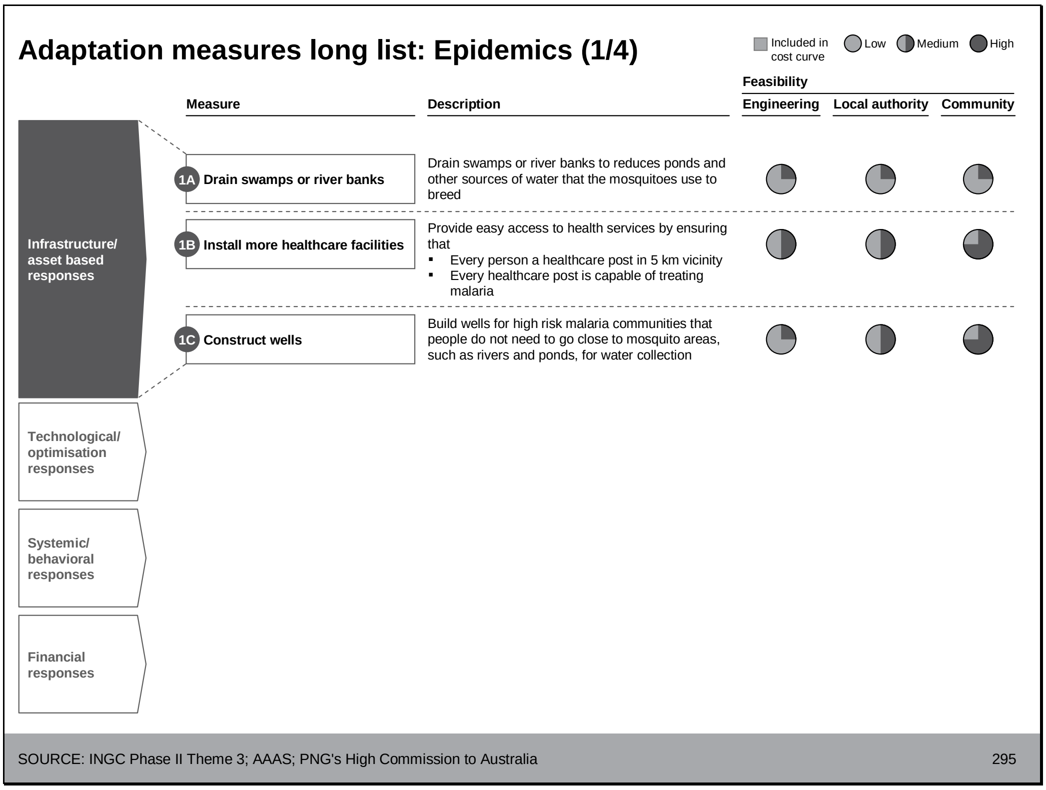
Adaptation measures long list: Wind damage

▨ Included in cost curve ○ Low ◑ Medium ● High

Response type	Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Infrastructure/ asset based responses					
Technological/ optimisation responses	**2A Wind-retrofit buildings**	Modify existing buildings to improve wind-resistance	◑	◔	◑
	2B Wind building codes	Construct new houses according to most recent knowledge and buildings standards	◕	◔	◔
Systemic/ behavioral responses					
Financial responses					

SOURCE: INGC Phase II Theme 3; AAAS; PNG's High Commission to Australia

SLIDE 296



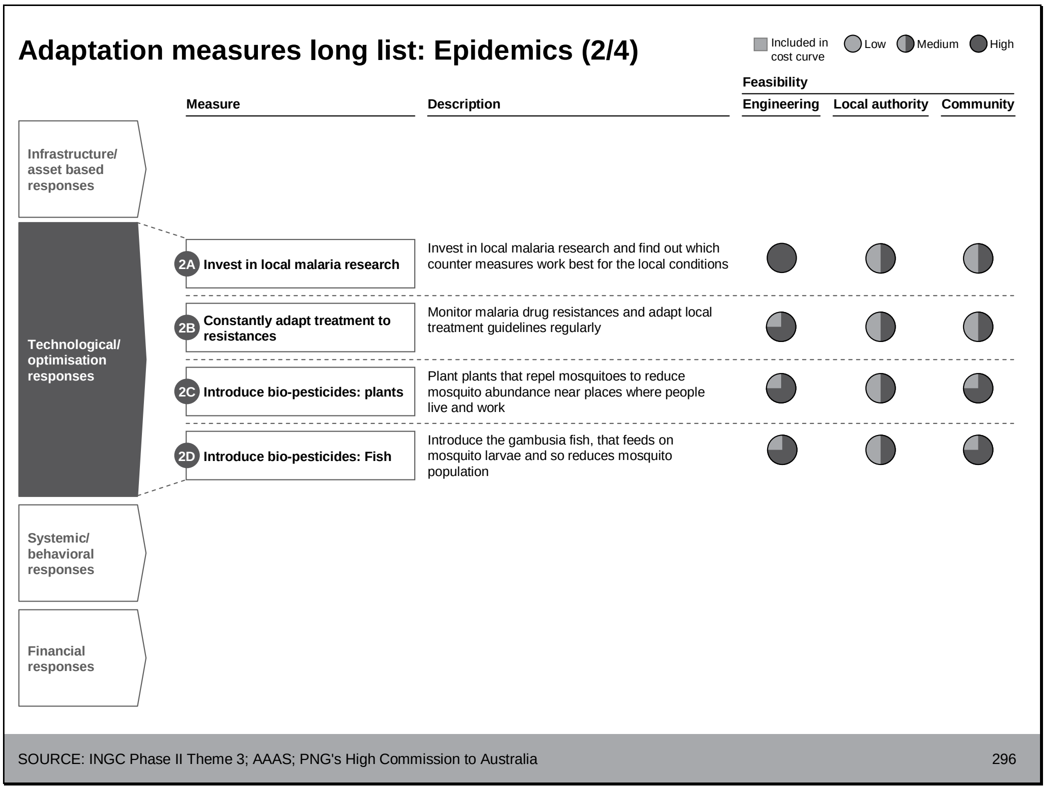
Adaptation measures long list: Epidemics (1/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Response type	Measure	Description	Feasibility: Engineering	Feasibility: Local authority	Feasibility: Community
Infrastructure/ asset based responses	**1A Drain swamps or river banks**	Drain swamps or river banks to reduces ponds and other sources of water that the mosquitoes use to breed	◔	◔	◔
	1B Install more healthcare facilities	Provide easy access to health services by ensuring that ▪ Every person a healthcare post in 5 km vicinity ▪ Every healthcare post is capable of treating malaria	◑	◑	◕
	1C Construct wells	Build wells for high risk malaria communities that people do not need to go close to mosquito areas, such as rivers and ponds, for water collection	◔	◑	◕
Technological/ optimisation responses					
Systemic/ behavioral responses					
Financial responses					

SOURCE: INGC Phase II Theme 3; AAAS; PNG's High Commission to Australia

SLIDE 297



Adaptation measures long list: Epidemics (2/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

Systemic/ behavioral responses

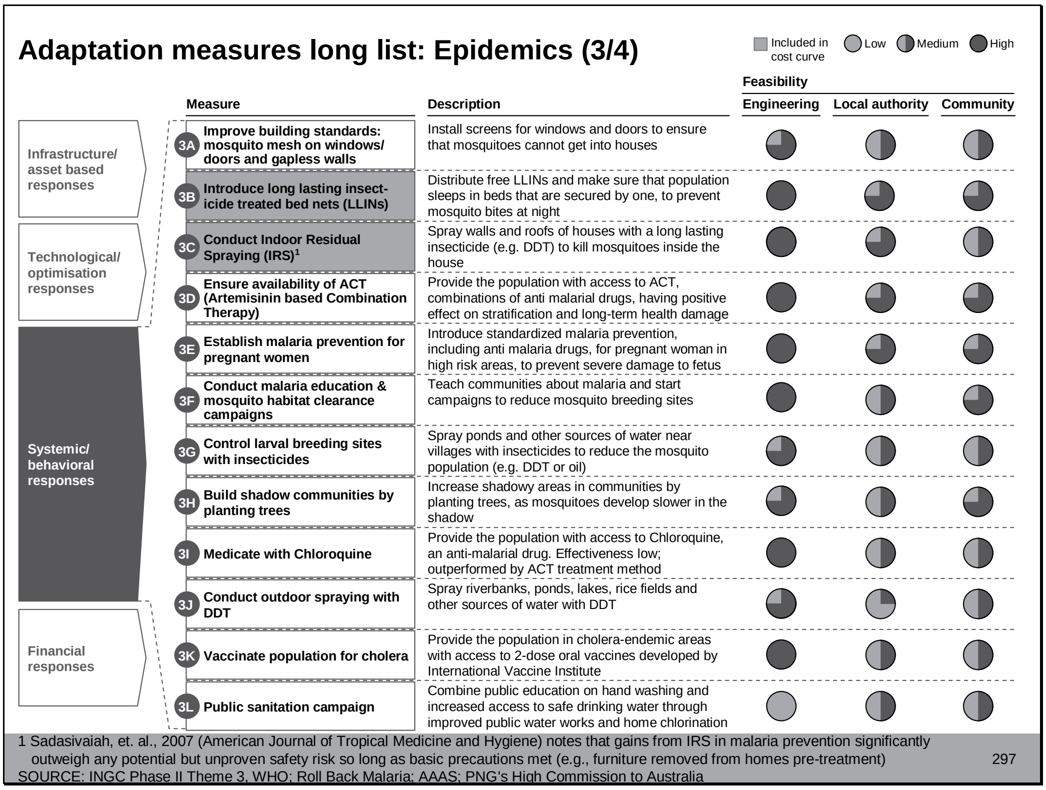
Financial responses

	Measure	Description	Feasibility Engineering	Local authority	Community
2A	**Invest in local malaria research**	Invest in local malaria research and find out which counter measures work best for the local conditions	●	◑	◑
2B	**Constantly adapt treatment to resistances**	Monitor malaria drug resistances and adapt local treatment guidelines regularly	◕	◑	◑
2C	**Introduce bio-pesticides: plants**	Plant plants that repel mosquitoes to reduce mosquito abundance near places where people live and work	◕	◑	◕
2D	**Introduce bio-pesticides: Fish**	Introduce the gambusia fish, that feeds on mosquito larvae and so reduces mosquito population	◕	◑	◕

SOURCE: INGC Phase II Theme 3; AAAS; PNG's High Commission to Australia

296

SLIDE 298



Adaptation measures long list: Epidemics (3/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

Infrastructure/ asset based responses

Technological/ optimisation responses

Systemic/ behavioral responses

Financial responses

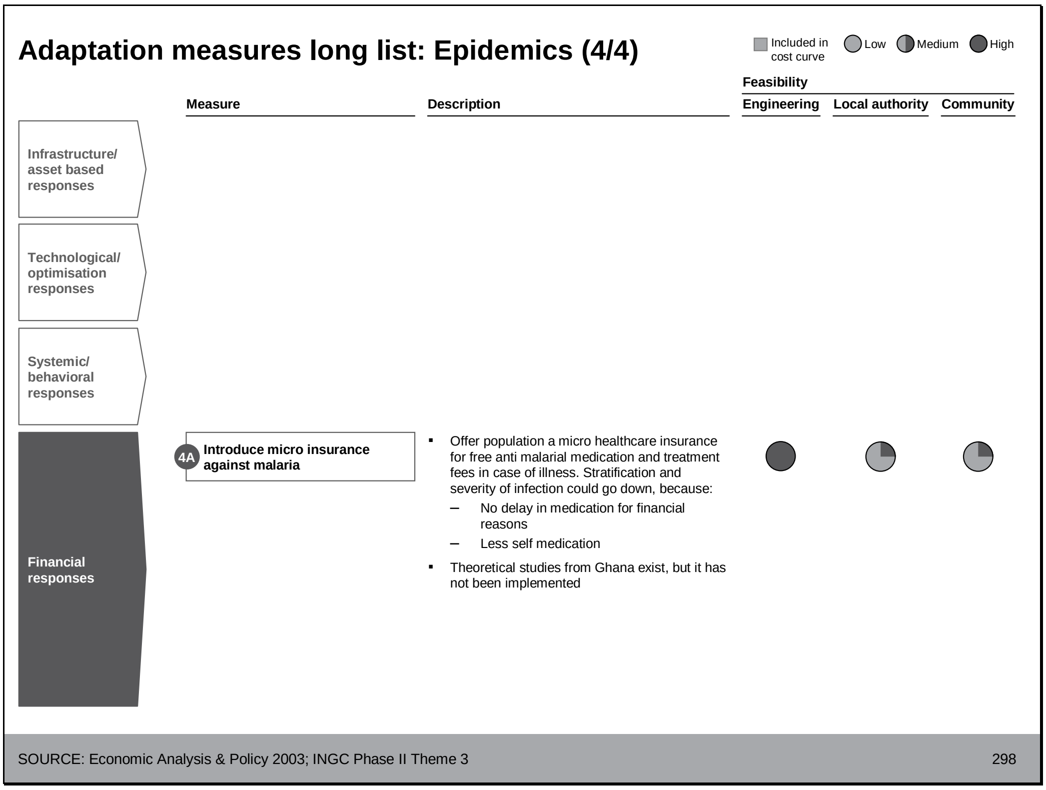
	Measure	Description	Feasibility Engineering	Local authority	Community
3A	**Improve building standards: mosquito mesh on windows/ doors and gapless walls**	Install screens for windows and doors to ensure that mosquitoes cannot get into houses	◕	◑	◑
3B	**Introduce long lasting insecticide treated bed nets (LLINs)**	Distribute free LLINs and make sure that population sleeps in beds that are secured by one, to prevent mosquito bites at night	●	◕	◕
3C	**Conduct Indoor Residual Spraying (IRS)**[1]	Spray walls and roofs of houses with a long lasting insecticide (e.g. DDT) to kill mosquitoes inside the house	●	◕	◑
3D	**Ensure availability of ACT (Artemisinin based Combination Therapy)**	Provide the population with access to ACT, combinations of anti malarial drugs, having positive effect on stratification and long-term health damage	●	◕	◕
3E	**Establish malaria prevention for pregnant women**	Introduce standardized malaria prevention, including anti malaria drugs, for pregnant woman in high risk areas, to prevent severe damage to fetus	●	◕	◕
3F	**Conduct malaria education & mosquito habitat clearance campaigns**	Teach communities about malaria and start campaigns to reduce mosquito breeding sites	●	◑	◕
3G	**Control larval breeding sites with insecticides**	Spray ponds and other sources of water near villages with insecticides to reduce the mosquito population (e.g. DDT or oil)	◕	◑	◑
3H	**Build shadow communities by planting trees**	Increase shadowy areas in communities by planting trees, as mosquitoes develop slower in the shadow	◕	◑	◕
3I	**Medicate with Chloroquine**	Provide the population with access to Chloroquine, an anti-malarial drug. Effectiveness low; outperformed by ACT treatment method	●	◑	◑
3J	**Conduct outdoor spraying with DDT**	Spray riverbanks, ponds, lakes, rice fields and other sources of water with DDT	◕	◔	◑
3K	**Vaccinate population for cholera**	Provide the population in cholera-endemic areas with access to 2-dose oral vaccines developed by International Vaccine Institute	●	◑	◑
3L	**Public sanitation campaign**	Combine public education on hand washing and increased access to safe drinking water through improved public water works and home chlorination	○	◑	◑

[1] Sadasivaiah, et. al., 2007 (American Journal of Tropical Medicine and Hygiene) notes that gains from IRS in malaria prevention significantly outweigh any potential but unproven safety risk so long as basic precautions met (e.g., furniture removed from homes pre-treatment)

SOURCE: INGC Phase II Theme 3, WHO; Roll Back Malaria; AAAS; PNG's High Commission to Australia

297

SLIDE 299



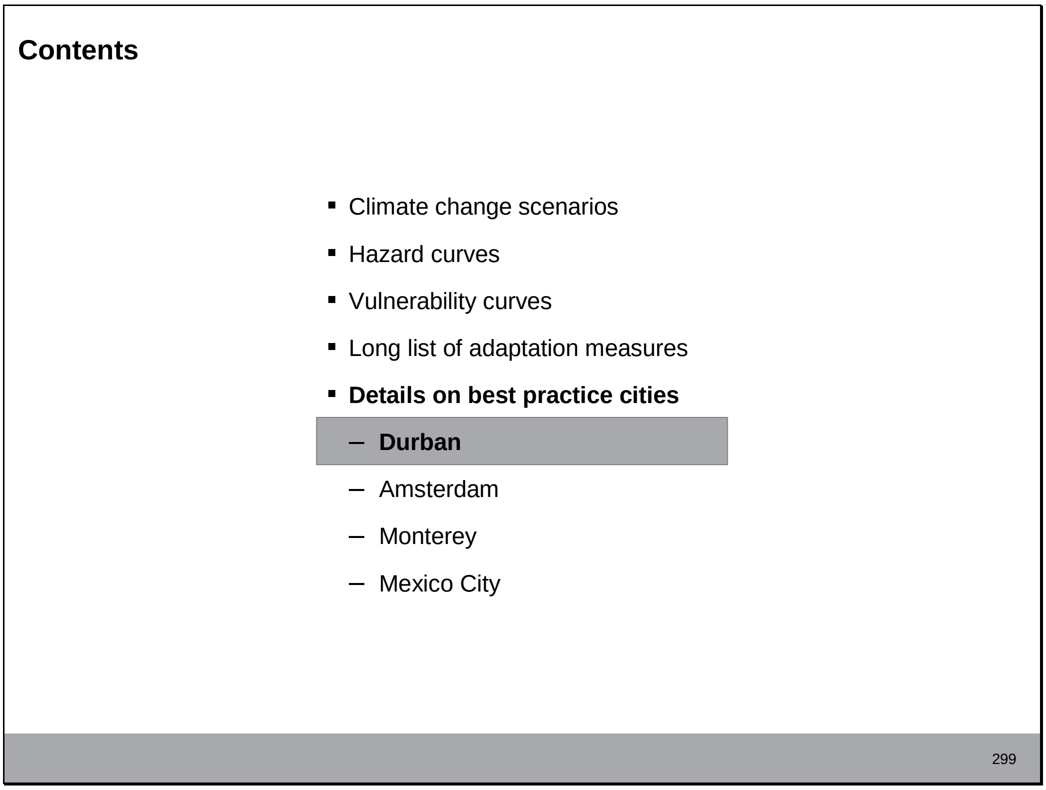
Adaptation measures long list: Epidemics (4/4)

▨ Included in cost curve ○ Low ◑ Medium ● High

	Measure	Description	Feasibility Engineering	 Local authority	 Community
Infrastructure/ asset based responses					
Technological/ optimisation responses					
Systemic/ behavioral responses					
Financial responses	4A Introduce micro insurance against malaria	▪ Offer population a micro healthcare insurance for free anti malarial medication and treatment fees in case of illness. Stratification and severity of infection could go down, because: – No delay in medication for financial reasons – Less self medication ▪ Theoretical studies from Ghana exist, but it has not been implemented	●	◔	◔

SOURCE: Economic Analysis & Policy 2003; INGC Phase II Theme 3

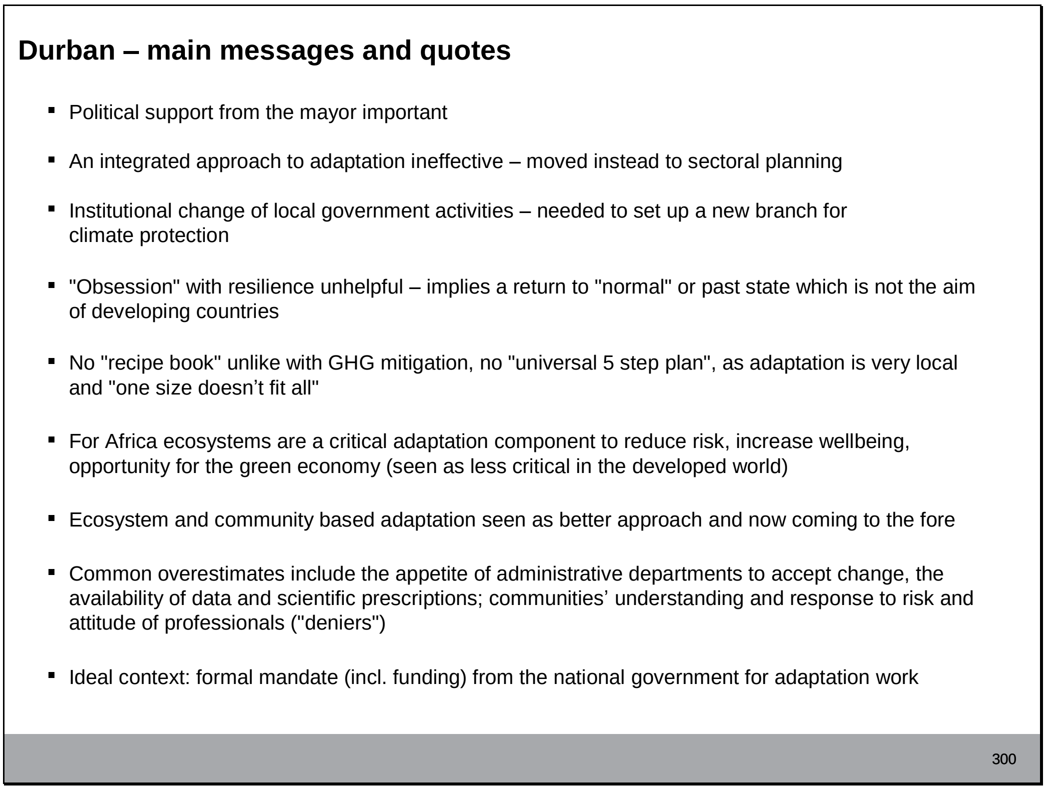
SLIDE 300



Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- **Details on best practice cities**
  - **Durban**
  - Amsterdam
  - Monterey
  - Mexico City

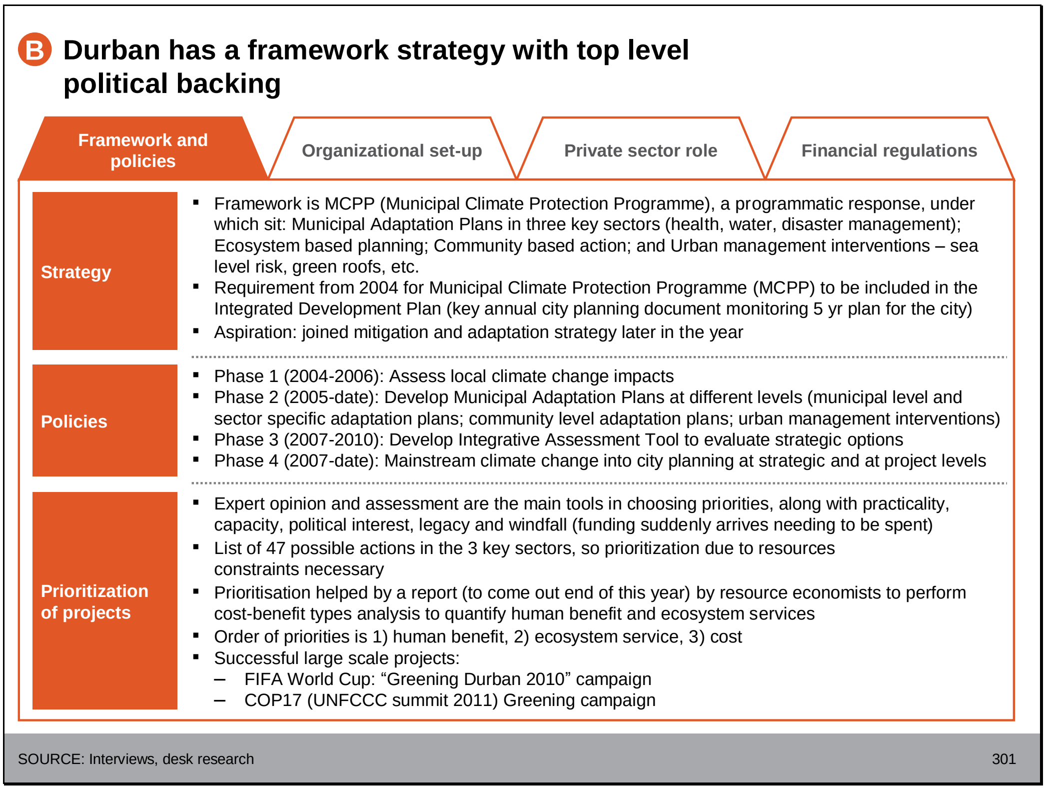
SLIDE 301



Durban – main messages and quotes

- Political support from the mayor important
- An integrated approach to adaptation ineffective – moved instead to sectoral planning
- Institutional change of local government activities – needed to set up a new branch for climate protection
- "Obsession" with resilience unhelpful – implies a return to "normal" or past state which is not the aim of developing countries
- No "recipe book" unlike with GHG mitigation, no "universal 5 step plan", as adaptation is very local and "one size doesn't fit all"
- For Africa ecosystems are a critical adaptation component to reduce risk, increase wellbeing, opportunity for the green economy (seen as less critical in the developed world)
- Ecosystem and community based adaptation seen as better approach and now coming to the fore
- Common overestimates include the appetite of administrative departments to accept change, the availability of data and scientific prescriptions; communities' understanding and response to risk and attitude of professionals ("deniers")
- Ideal context: formal mandate (incl. funding) from the national government for adaptation work

SLIDE 302



B Durban has a framework strategy with top level political backing

Strategy

- Framework is MCPP (Municipal Climate Protection Programme), a programmatic response, under which sit: Municipal Adaptation Plans in three key sectors (health, water, disaster management); Ecosystem based planning; Community based action; and Urban management interventions – sea level risk, green roofs, etc.
- Requirement from 2004 for Municipal Climate Protection Programme (MCPP) to be included in the Integrated Development Plan (key annual city planning document monitoring 5 yr plan for the city)
- Aspiration: joined mitigation and adaptation strategy later in the year

Policies

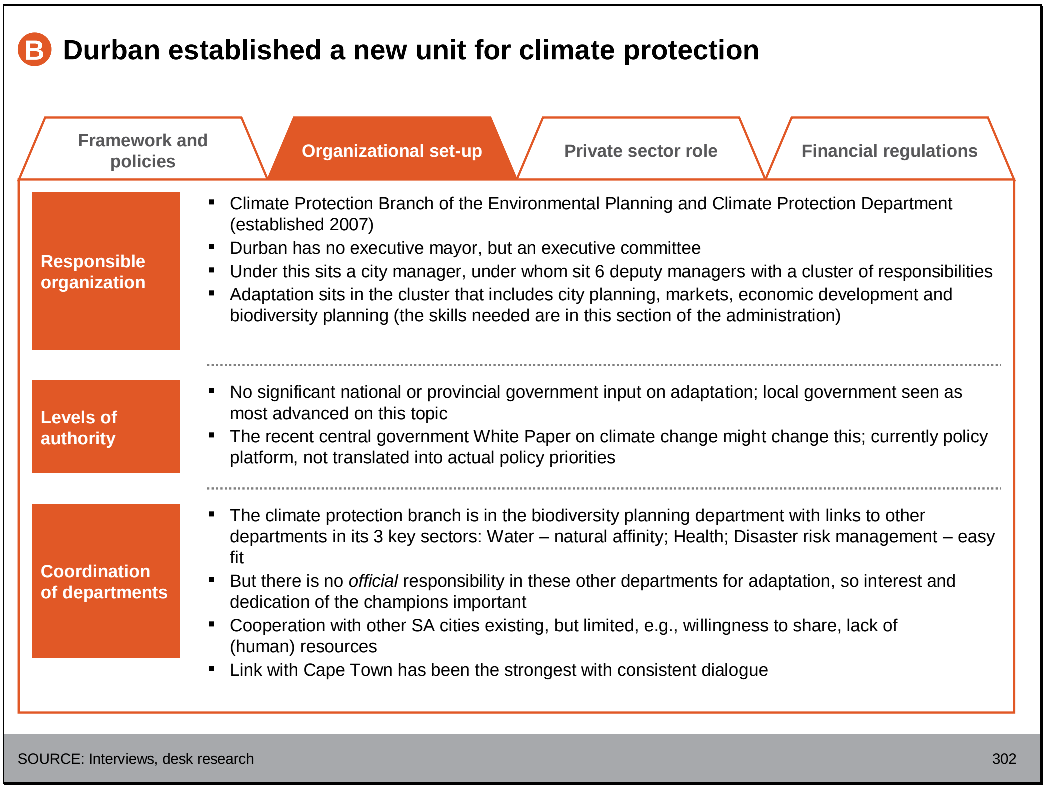
- Phase 1 (2004-2006): Assess local climate change impacts
- Phase 2 (2005-date): Develop Municipal Adaptation Plans at different levels (municipal level and sector specific adaptation plans; community level adaptation plans; urban management interventions)
- Phase 3 (2007-2010): Develop Integrative Assessment Tool to evaluate strategic options
- Phase 4 (2007-date): Mainstream climate change into city planning at strategic and at project levels

Prioritization of projects

- Expert opinion and assessment are the main tools in choosing priorities, along with practicality, capacity, political interest, legacy and windfall (funding suddenly arrives needing to be spent)
- List of 47 possible actions in the 3 key sectors, so prioritization due to resources constraints necessary
- Prioritisation helped by a report (to come out end of this year) by resource economists to perform cost-benefit types analysis to quantify human benefit and ecosystem services
- Order of priorities is 1) human benefit, 2) ecosystem service, 3) cost
- Successful large scale projects:
  - FIFA World Cup: "Greening Durban 2010" campaign
  - COP17 (UNFCCC summit 2011) Greening campaign

SOURCE: Interviews, desk research

SLIDE 303



B Durban established a new unit for climate protection

Framework and policies | **Organizational set-up** | Private sector role | Financial regulations

Responsible organization

- Climate Protection Branch of the Environmental Planning and Climate Protection Department (established 2007)
- Durban has no executive mayor, but an executive committee
- Under this sits a city manager, under whom sit 6 deputy managers with a cluster of responsibilities
- Adaptation sits in the cluster that includes city planning, markets, economic development and biodiversity planning (the skills needed are in this section of the administration)

Levels of authority

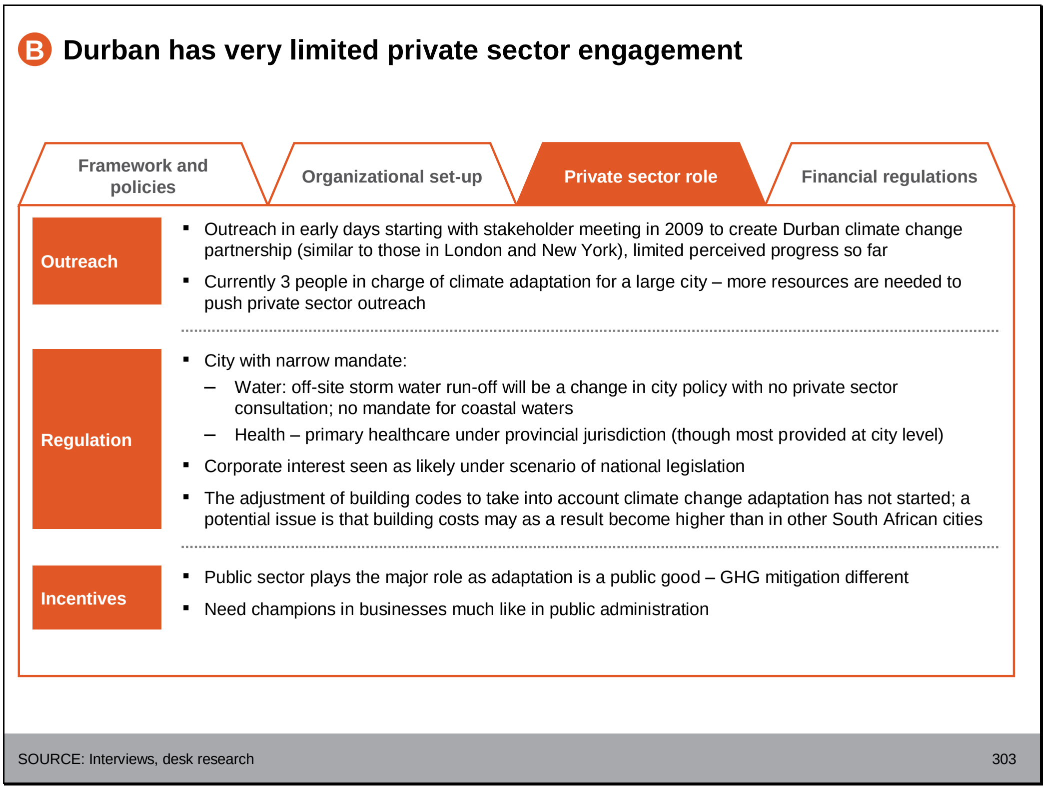
- No significant national or provincial government input on adaptation; local government seen as most advanced on this topic
- The recent central government White Paper on climate change might change this; currently policy platform, not translated into actual policy priorities

Coordination of departments

- The climate protection branch is in the biodiversity planning department with links to other departments in its 3 key sectors: Water – natural affinity; Health; Disaster risk management – easy fit
- But there is no *official* responsibility in these other departments for adaptation, so interest and dedication of the champions important
- Cooperation with other SA cities existing, but limited, e.g., willingness to share, lack of (human) resources
- Link with Cape Town has been the strongest with consistent dialogue

SOURCE: Interviews, desk research

SLIDE 304



B Durban has very limited private sector engagement

Framework and policies | Organizational set-up | **Private sector role** | Financial regulations

Outreach

- Outreach in early days starting with stakeholder meeting in 2009 to create Durban climate change partnership (similar to those in London and New York), limited perceived progress so far
- Currently 3 people in charge of climate adaptation for a large city – more resources are needed to push private sector outreach

Regulation

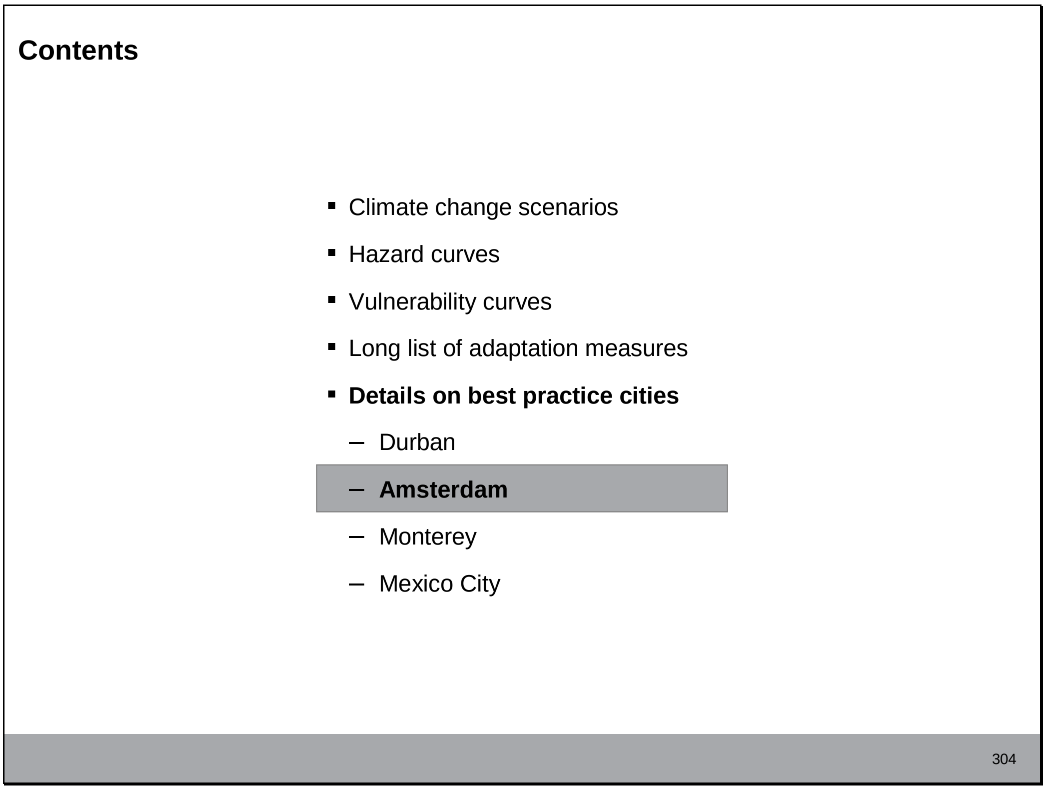
- City with narrow mandate:
  - Water: off-site storm water run-off will be a change in city policy with no private sector consultation; no mandate for coastal waters
  - Health – primary healthcare under provincial jurisdiction (though most provided at city level)
- Corporate interest seen as likely under scenario of national legislation
- The adjustment of building codes to take into account climate change adaptation has not started; a potential issue is that building costs may as a result become higher than in other South African cities

Incentives

- Public sector plays the major role as adaptation is a public good – GHG mitigation different
- Need champions in businesses much like in public administration

SOURCE: Interviews, desk research

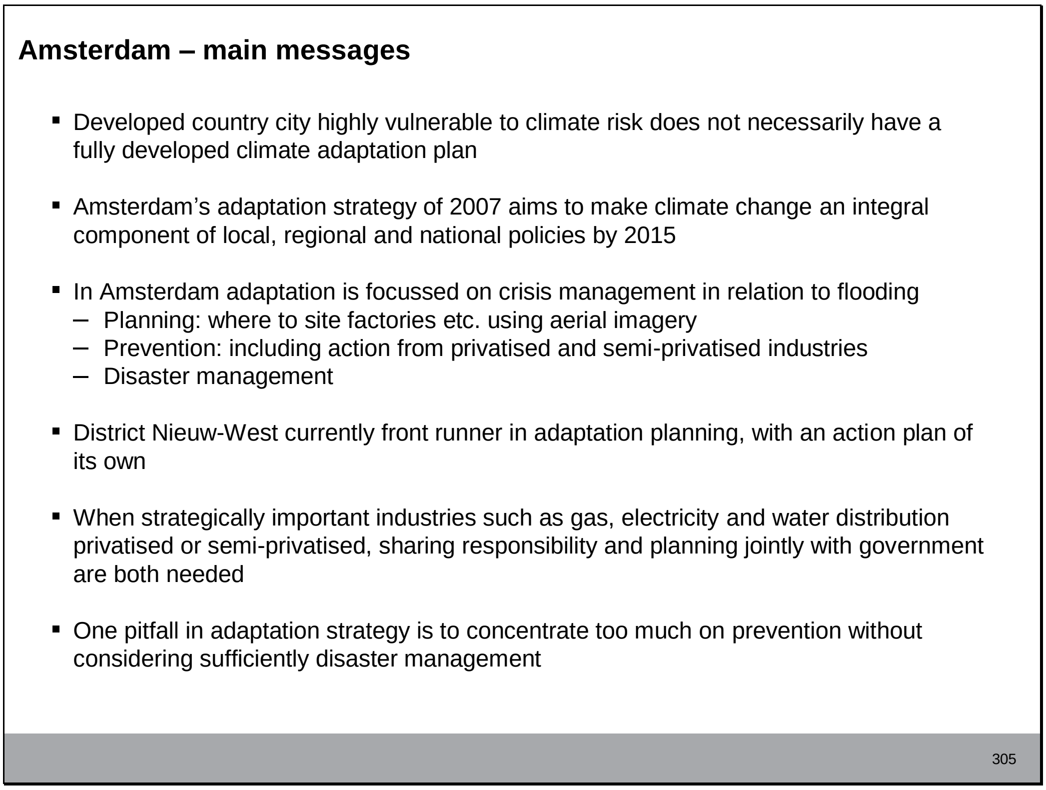
SLIDE 305



Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- **Details on best practice cities**
  - Durban
  - **Amsterdam**
  - Monterey
  - Mexico City

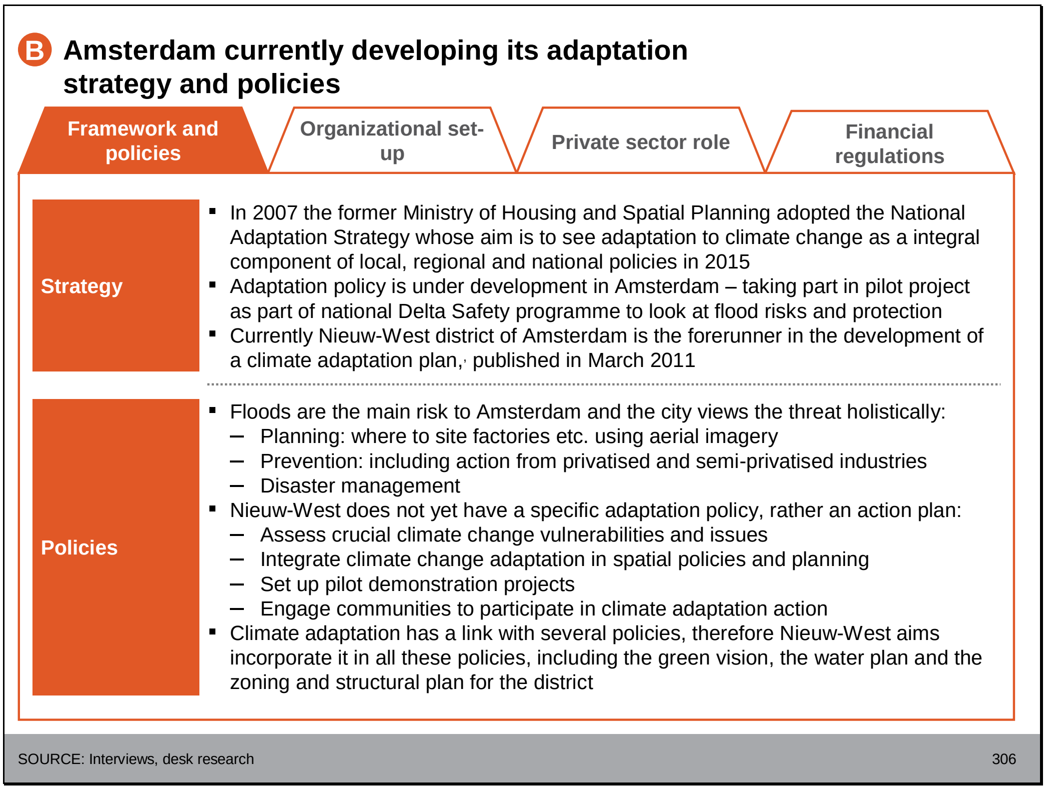
SLIDE 306



Amsterdam – main messages

- Developed country city highly vulnerable to climate risk does not necessarily have a fully developed climate adaptation plan
- Amsterdam's adaptation strategy of 2007 aims to make climate change an integral component of local, regional and national policies by 2015
- In Amsterdam adaptation is focussed on crisis management in relation to flooding
  - Planning: where to site factories etc. using aerial imagery
  - Prevention: including action from privatised and semi-privatised industries
  - Disaster management
- District Nieuw-West currently front runner in adaptation planning, with an action plan of its own
- When strategically important industries such as gas, electricity and water distribution privatised or semi-privatised, sharing responsibility and planning jointly with government are both needed
- One pitfall in adaptation strategy is to concentrate too much on prevention without considering sufficiently disaster management

SLIDE 307



B Amsterdam currently developing its adaptation strategy and policies

Framework and policies | Organizational set-up | Private sector role | Financial regulations

Strategy

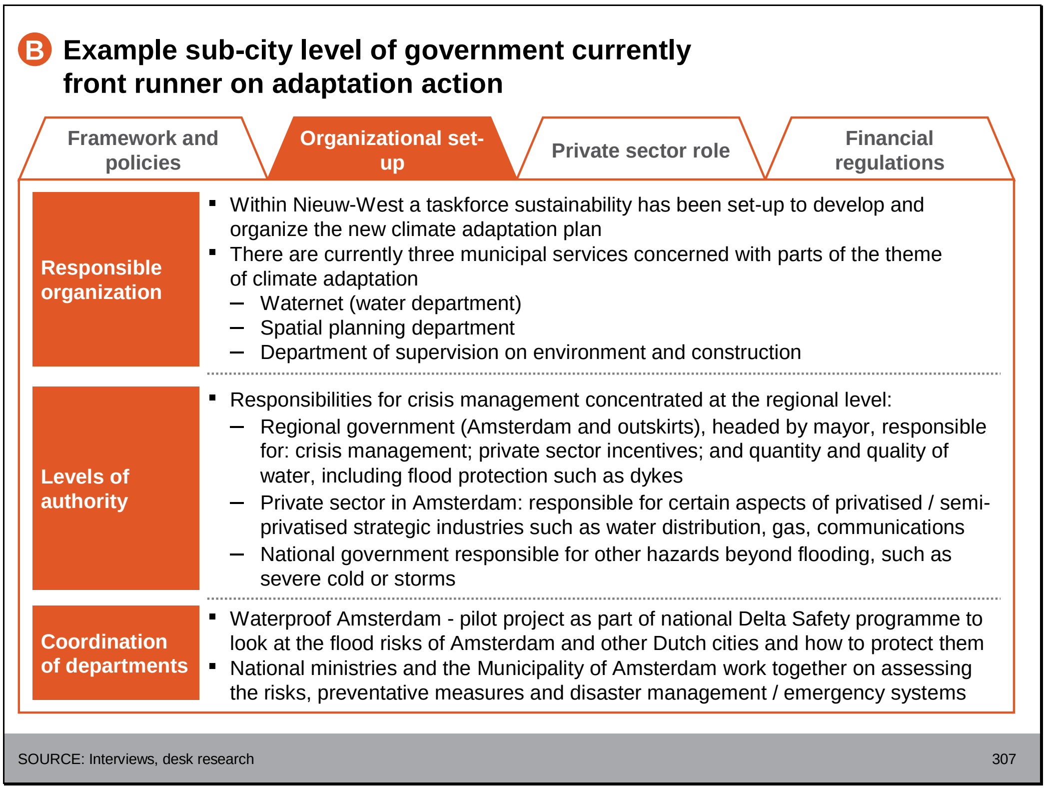
- In 2007 the former Ministry of Housing and Spatial Planning adopted the National Adaptation Strategy whose aim is to see adaptation to climate change as a integral component of local, regional and national policies in 2015
- Adaptation policy is under development in Amsterdam – taking part in pilot project as part of national Delta Safety programme to look at flood risks and protection
- Currently Nieuw-West district of Amsterdam is the forerunner in the development of a climate adaptation plan, published in March 2011

Policies

- Floods are the main risk to Amsterdam and the city views the threat holistically:
  - Planning: where to site factories etc. using aerial imagery
  - Prevention: including action from privatised and semi-privatised industries
  - Disaster management
- Nieuw-West does not yet have a specific adaptation policy, rather an action plan:
  - Assess crucial climate change vulnerabilities and issues
  - Integrate climate change adaptation in spatial policies and planning
  - Set up pilot demonstration projects
  - Engage communities to participate in climate adaptation action
- Climate adaptation has a link with several policies, therefore Nieuw-West aims incorporate it in all these policies, including the green vision, the water plan and the zoning and structural plan for the district

SOURCE: Interviews, desk research

SLIDE 308



B Example sub-city level of government currently front runner on adaptation action

Framework and policies | **Organizational set-up** | Private sector role | Financial regulations

Responsible organization

- Within Nieuw-West a taskforce sustainability has been set-up to develop and organize the new climate adaptation plan
- There are currently three municipal services concerned with parts of the theme of climate adaptation
  - Waternet (water department)
  - Spatial planning department
  - Department of supervision on environment and construction

Levels of authority

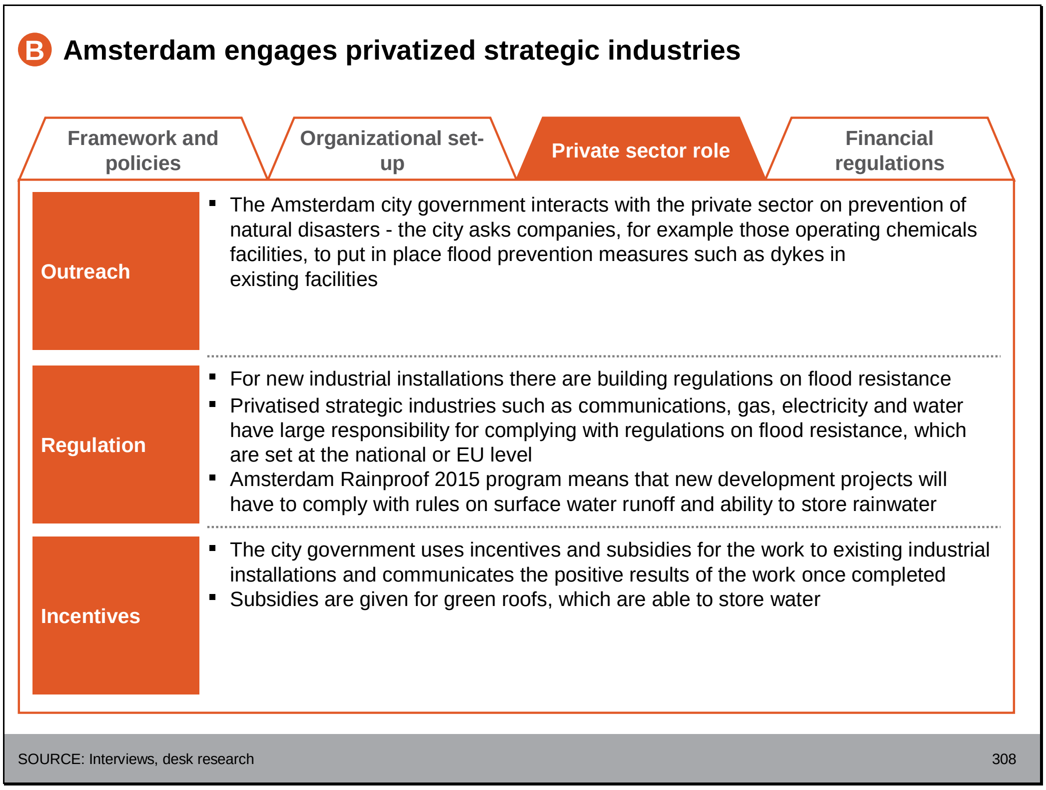
- Responsibilities for crisis management concentrated at the regional level:
  - Regional government (Amsterdam and outskirts), headed by mayor, responsible for: crisis management; private sector incentives; and quantity and quality of water, including flood protection such as dykes
  - Private sector in Amsterdam: responsible for certain aspects of privatised / semi-privatised strategic industries such as water distribution, gas, communications
  - National government responsible for other hazards beyond flooding, such as severe cold or storms

Coordination of departments

- Waterproof Amsterdam - pilot project as part of national Delta Safety programme to look at the flood risks of Amsterdam and other Dutch cities and how to protect them
- National ministries and the Municipality of Amsterdam work together on assessing the risks, preventative measures and disaster management / emergency systems

SOURCE: Interviews, desk research

SLIDE 309



B Amsterdam engages privatized strategic industries

Framework and policies | Organizational set-up | **Private sector role** | Financial regulations

Outreach

- The Amsterdam city government interacts with the private sector on prevention of natural disasters - the city asks companies, for example those operating chemicals facilities, to put in place flood prevention measures such as dykes in existing facilities

Regulation

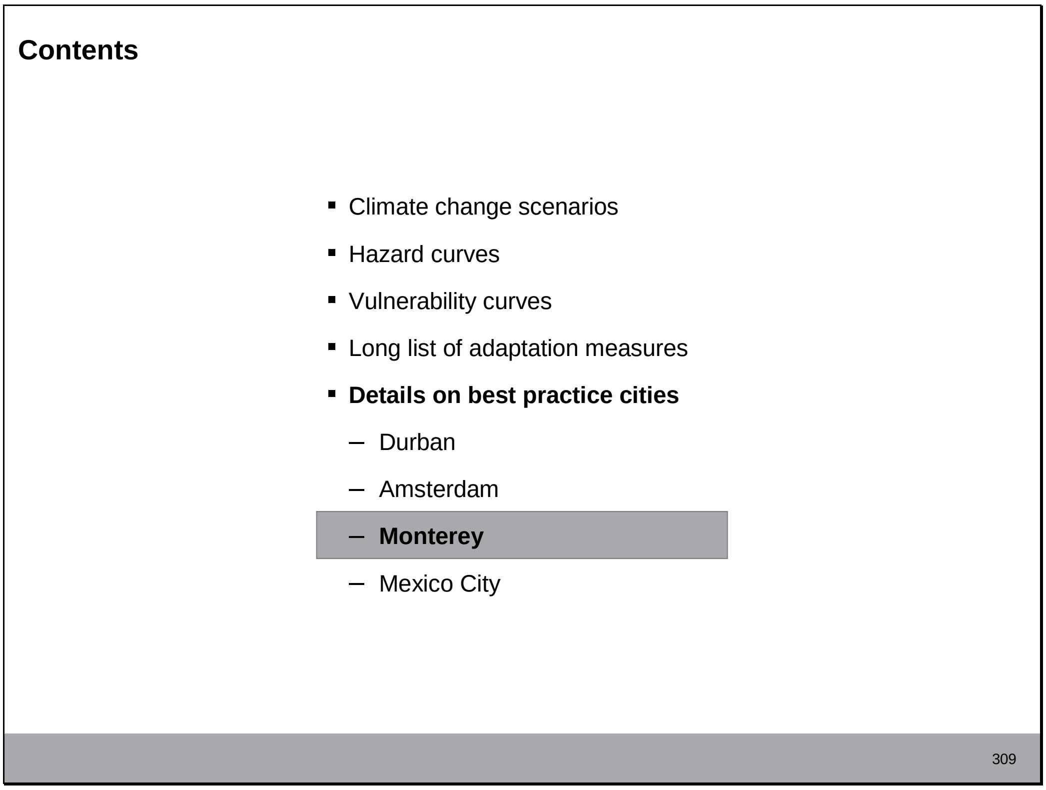
- For new industrial installations there are building regulations on flood resistance
- Privatised strategic industries such as communications, gas, electricity and water have large responsibility for complying with regulations on flood resistance, which are set at the national or EU level
- Amsterdam Rainproof 2015 program means that new development projects will have to comply with rules on surface water runoff and ability to store rainwater

Incentives

- The city government uses incentives and subsidies for the work to existing industrial installations and communicates the positive results of the work once completed
- Subsidies are given for green roofs, which are able to store water

SOURCE: Interviews, desk research

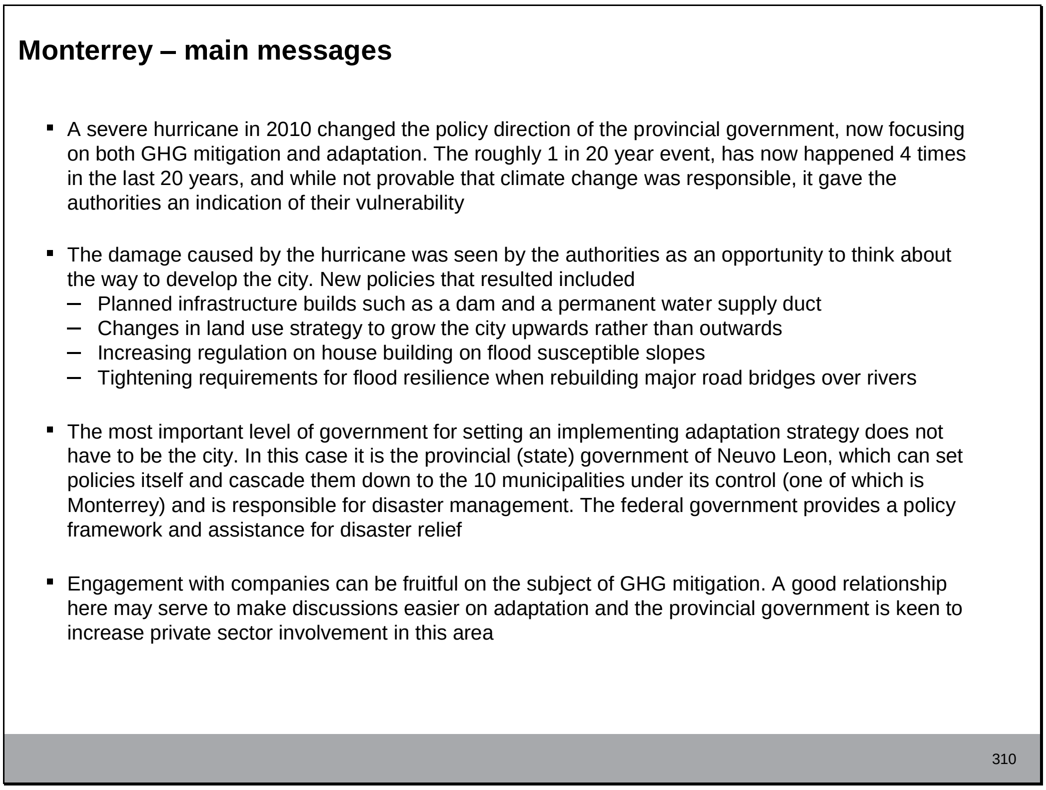
SLIDE 310



Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- **Details on best practice cities**
  - Durban
  - Amsterdam
  - **Monterey**
  - Mexico City

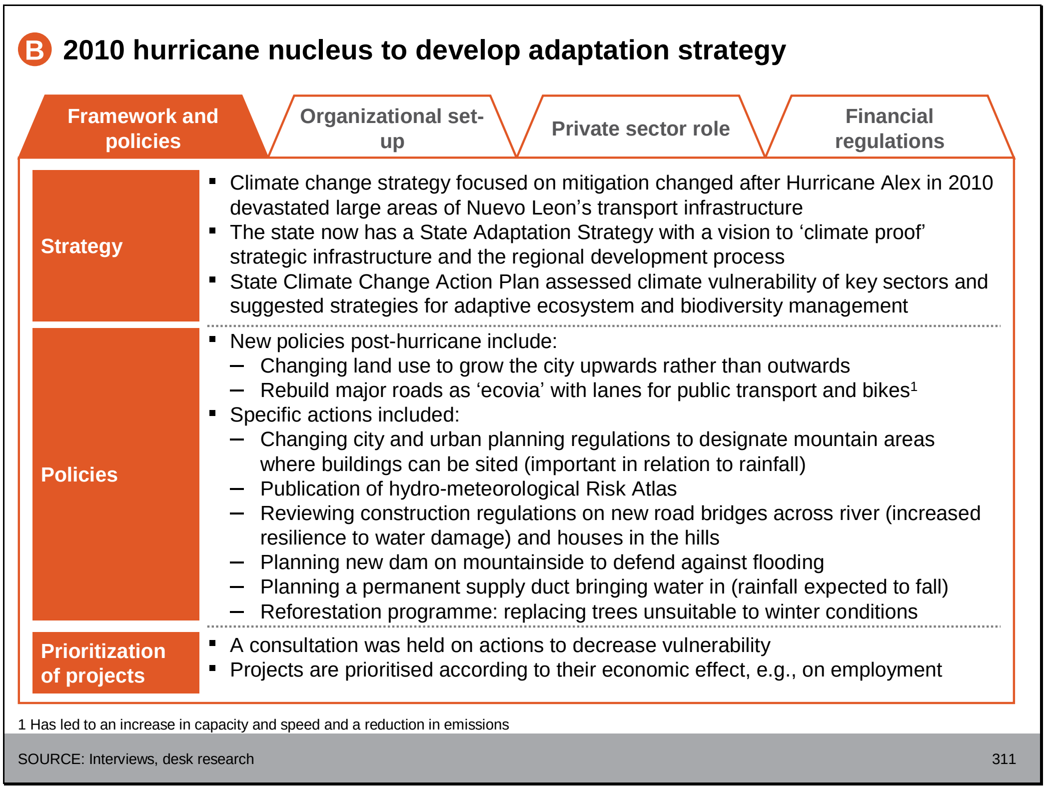
SLIDE 311



Monterrey – main messages

- A severe hurricane in 2010 changed the policy direction of the provincial government, now focusing on both GHG mitigation and adaptation. The roughly 1 in 20 year event, has now happened 4 times in the last 20 years, and while not provable that climate change was responsible, it gave the authorities an indication of their vulnerability
- The damage caused by the hurricane was seen by the authorities as an opportunity to think about the way to develop the city. New policies that resulted included
  - Planned infrastructure builds such as a dam and a permanent water supply duct
  - Changes in land use strategy to grow the city upwards rather than outwards
  - Increasing regulation on house building on flood susceptible slopes
  - Tightening requirements for flood resilience when rebuilding major road bridges over rivers
- The most important level of government for setting an implementing adaptation strategy does not have to be the city. In this case it is the provincial (state) government of Neuvo Leon, which can set policies itself and cascade them down to the 10 municipalities under its control (one of which is Monterrey) and is responsible for disaster management. The federal government provides a policy framework and assistance for disaster relief
- Engagement with companies can be fruitful on the subject of GHG mitigation. A good relationship here may serve to make discussions easier on adaptation and the provincial government is keen to increase private sector involvement in this area

SLIDE 312



B 2010 hurricane nucleus to develop adaptation strategy

Strategy

- Climate change strategy focused on mitigation changed after Hurricane Alex in 2010 devastated large areas of Nuevo Leon's transport infrastructure
- The state now has a State Adaptation Strategy with a vision to 'climate proof' strategic infrastructure and the regional development process
- State Climate Change Action Plan assessed climate vulnerability of key sectors and suggested strategies for adaptive ecosystem and biodiversity management

Policies

- New policies post-hurricane include:
  - Changing land use to grow the city upwards rather than outwards
  - Rebuild major roads as 'ecovia' with lanes for public transport and bikes[1]
- Specific actions included:
  - Changing city and urban planning regulations to designate mountain areas where buildings can be sited (important in relation to rainfall)
  - Publication of hydro-meteorological Risk Atlas
  - Reviewing construction regulations on new road bridges across river (increased resilience to water damage) and houses in the hills
  - Planning new dam on mountainside to defend against flooding
  - Planning a permanent supply duct bringing water in (rainfall expected to fall)
  - Reforestation programme: replacing trees unsuitable to winter conditions

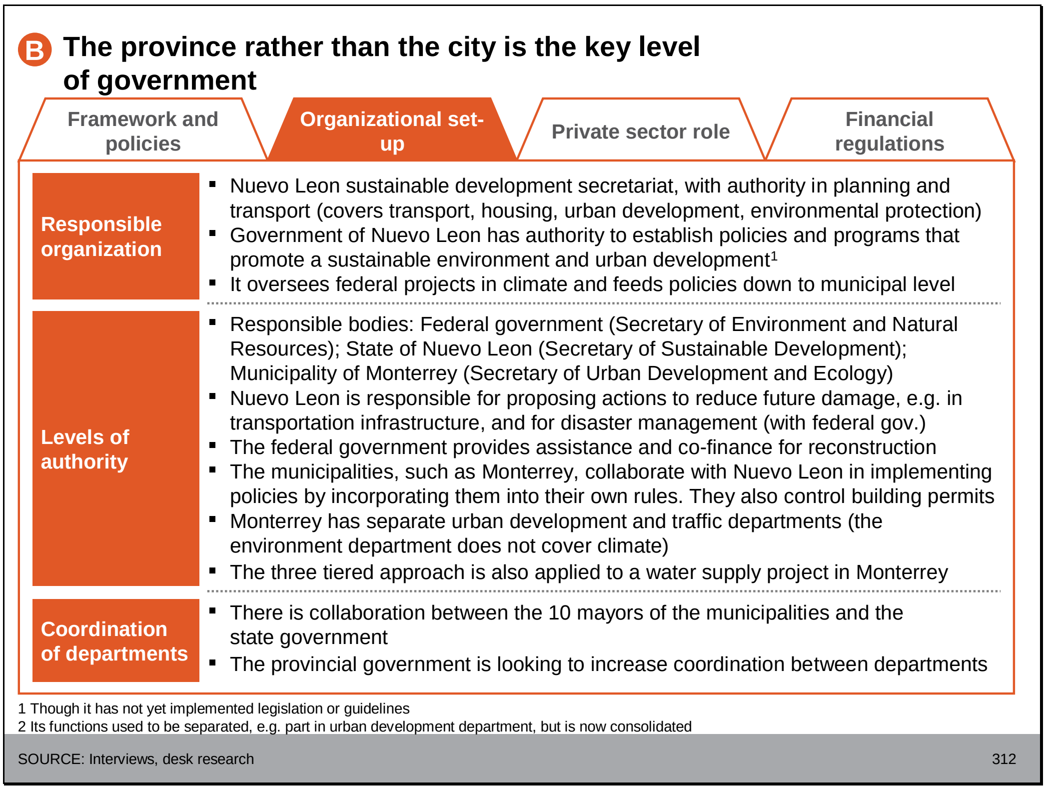
Prioritization of projects

- A consultation was held on actions to decrease vulnerability
- Projects are prioritised according to their economic effect, e.g., on employment

1 Has led to an increase in capacity and speed and a reduction in emissions

SOURCE: Interviews, desk research

SLIDE 313



B The province rather than the city is the key level of government

Framework and policies | **Organizational set-up** | Private sector role | Financial regulations

Responsible organization
- Nuevo Leon sustainable development secretariat, with authority in planning and transport (covers transport, housing, urban development, environmental protection)
- Government of Nuevo Leon has authority to establish policies and programs that promote a sustainable environment and urban development[1]
- It oversees federal projects in climate and feeds policies down to municipal level

Levels of authority
- Responsible bodies: Federal government (Secretary of Environment and Natural Resources); State of Nuevo Leon (Secretary of Sustainable Development); Municipality of Monterrey (Secretary of Urban Development and Ecology)
- Nuevo Leon is responsible for proposing actions to reduce future damage, e.g. in transportation infrastructure, and for disaster management (with federal gov.)
- The federal government provides assistance and co-finance for reconstruction
- The municipalities, such as Monterrey, collaborate with Nuevo Leon in implementing policies by incorporating them into their own rules. They also control building permits
- Monterrey has separate urban development and traffic departments (the environment department does not cover climate)
- The three tiered approach is also applied to a water supply project in Monterrey

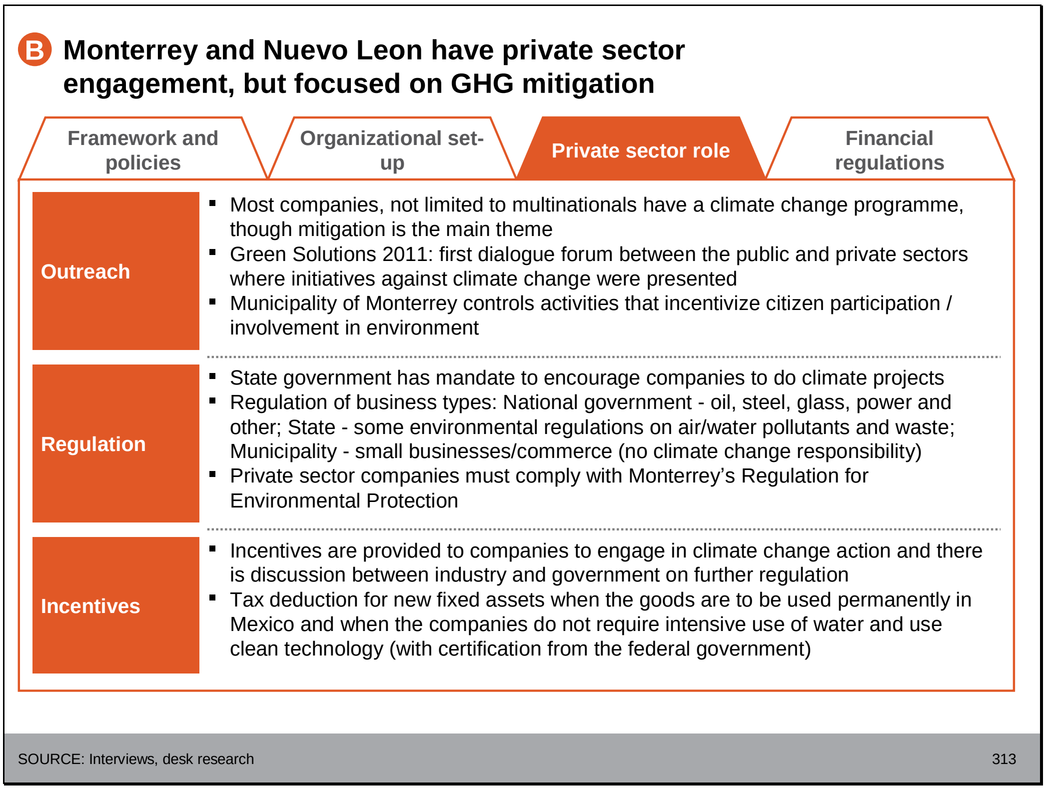
Coordination of departments
- There is collaboration between the 10 mayors of the municipalities and the state government
- The provincial government is looking to increase coordination between departments

1 Though it has not yet implemented legislation or guidelines
2 Its functions used to be separated, e.g. part in urban development department, but is now consolidated

SOURCE: Interviews, desk research

312

SLIDE 314



B Monterrey and Nuevo Leon have private sector engagement, but focused on GHG mitigation

Framework and policies | Organizational set-up | **Private sector role** | Financial regulations

Outreach
- Most companies, not limited to multinationals have a climate change programme, though mitigation is the main theme
- Green Solutions 2011: first dialogue forum between the public and private sectors where initiatives against climate change were presented
- Municipality of Monterrey controls activities that incentivize citizen participation / involvement in environment

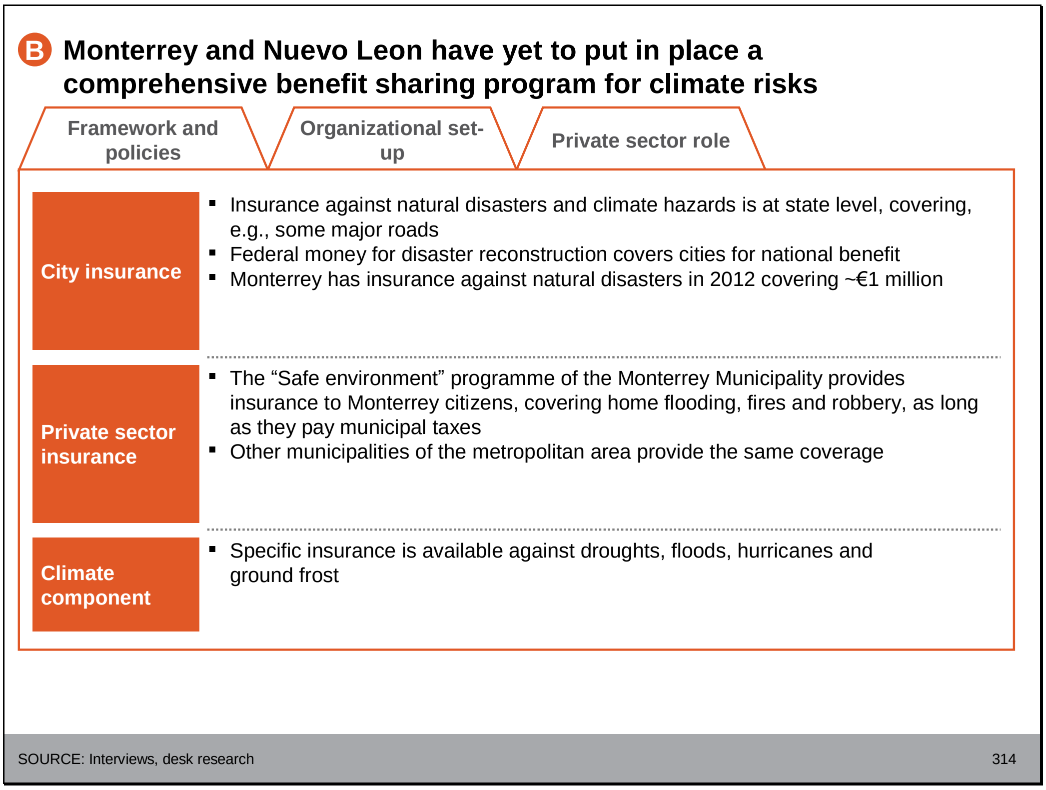
Regulation
- State government has mandate to encourage companies to do climate projects
- Regulation of business types: National government - oil, steel, glass, power and other; State - some environmental regulations on air/water pollutants and waste; Municipality - small businesses/commerce (no climate change responsibility)
- Private sector companies must comply with Monterrey's Regulation for Environmental Protection

Incentives
- Incentives are provided to companies to engage in climate change action and there is discussion between industry and government on further regulation
- Tax deduction for new fixed assets when the goods are to be used permanently in Mexico and when the companies do not require intensive use of water and use clean technology (with certification from the federal government)

SOURCE: Interviews, desk research

313

SLIDE 315



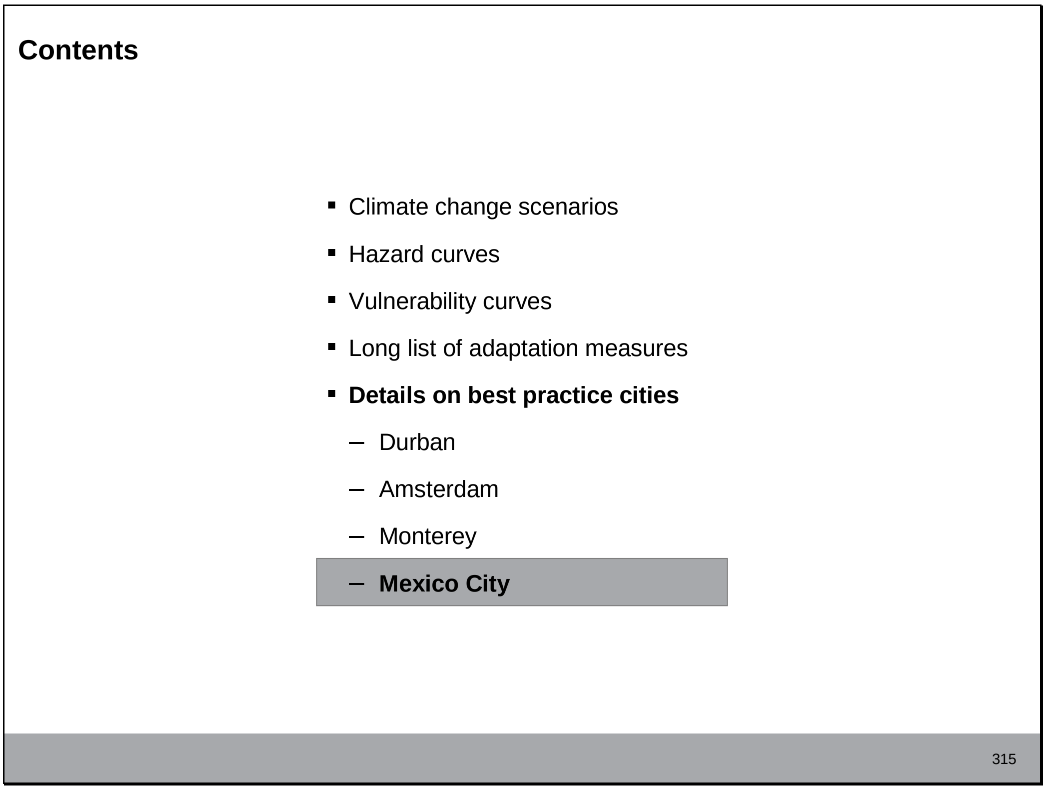
B Monterrey and Nuevo Leon have yet to put in place a comprehensive benefit sharing program for climate risks

Framework and policies | Organizational set-up | Private sector role

City insurance	▪ Insurance against natural disasters and climate hazards is at state level, covering, e.g., some major roads ▪ Federal money for disaster reconstruction covers cities for national benefit ▪ Monterrey has insurance against natural disasters in 2012 covering ~€1 million
Private sector insurance	▪ The “Safe environment” programme of the Monterrey Municipality provides insurance to Monterrey citizens, covering home flooding, fires and robbery, as long as they pay municipal taxes ▪ Other municipalities of the metropolitan area provide the same coverage
Climate component	▪ Specific insurance is available against droughts, floods, hurricanes and ground frost

SOURCE: Interviews, desk research

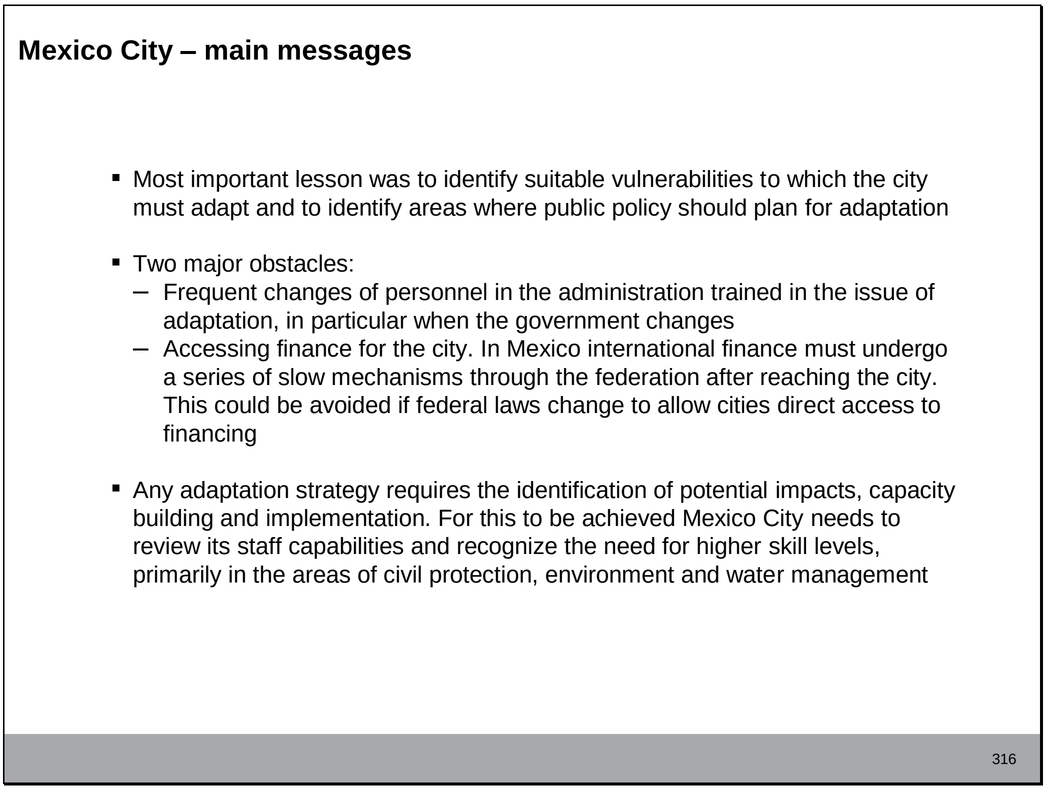
SLIDE 316



Contents

- Climate change scenarios
- Hazard curves
- Vulnerability curves
- Long list of adaptation measures
- **Details on best practice cities**
  - Durban
  - Amsterdam
  - Monterey
  - **Mexico City**

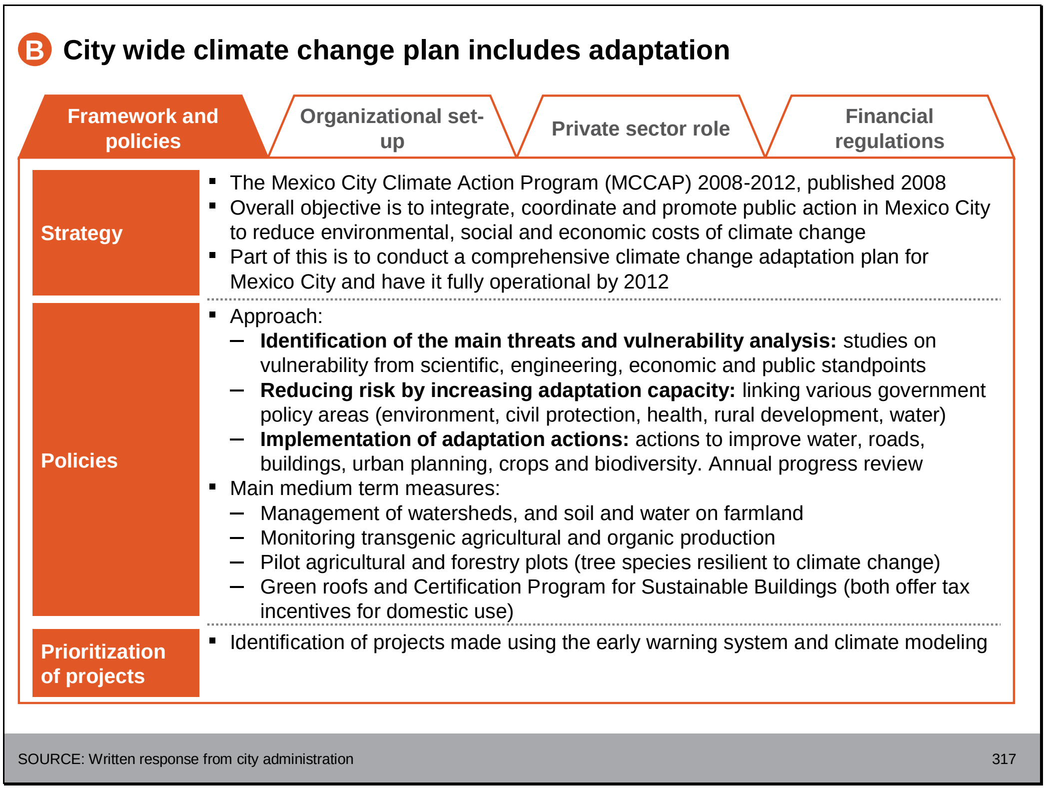
SLIDE 317



Mexico City – main messages

- Most important lesson was to identify suitable vulnerabilities to which the city must adapt and to identify areas where public policy should plan for adaptation
- Two major obstacles:
  - Frequent changes of personnel in the administration trained in the issue of adaptation, in particular when the government changes
  - Accessing finance for the city. In Mexico international finance must undergo a series of slow mechanisms through the federation after reaching the city. This could be avoided if federal laws change to allow cities direct access to financing
- Any adaptation strategy requires the identification of potential impacts, capacity building and implementation. For this to be achieved Mexico City needs to review its staff capabilities and recognize the need for higher skill levels, primarily in the areas of civil protection, environment and water management

SLIDE 318



B City wide climate change plan includes adaptation

Strategy

- The Mexico City Climate Action Program (MCCAP) 2008-2012, published 2008
- Overall objective is to integrate, coordinate and promote public action in Mexico City to reduce environmental, social and economic costs of climate change
- Part of this is to conduct a comprehensive climate change adaptation plan for Mexico City and have it fully operational by 2012

Policies

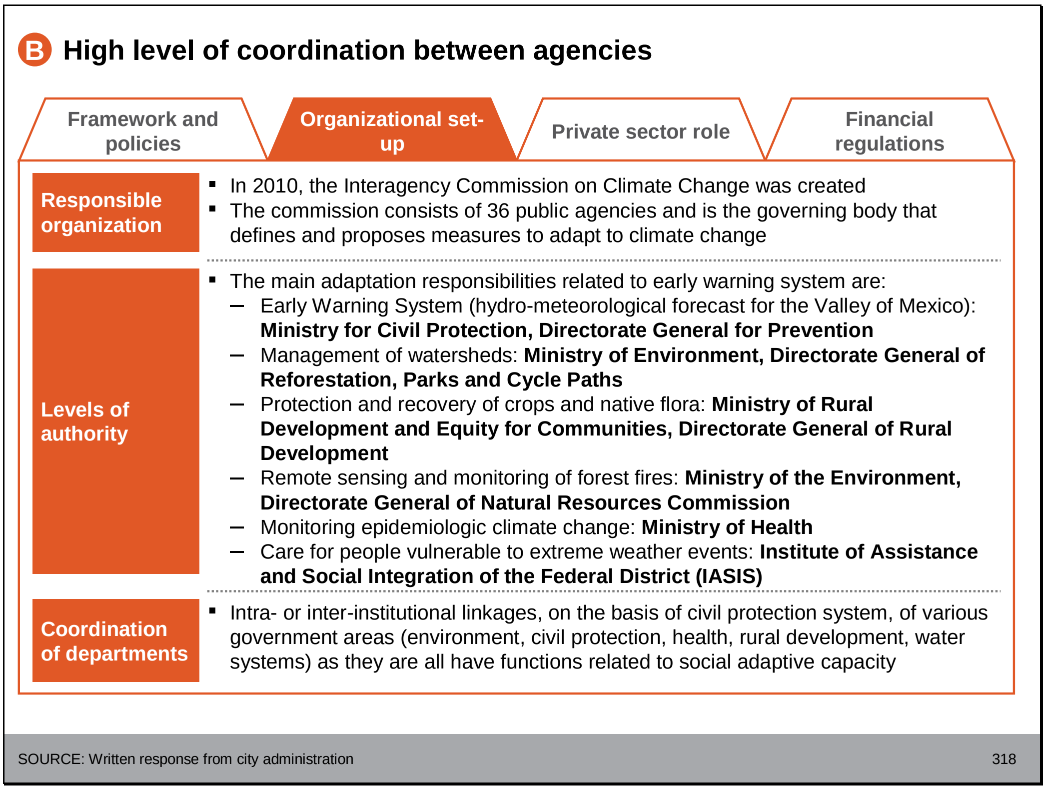
- Approach:
  - **Identification of the main threats and vulnerability analysis:** studies on vulnerability from scientific, engineering, economic and public standpoints
  - **Reducing risk by increasing adaptation capacity:** linking various government policy areas (environment, civil protection, health, rural development, water)
  - **Implementation of adaptation actions:** actions to improve water, roads, buildings, urban planning, crops and biodiversity. Annual progress review
- Main medium term measures:
  - Management of watersheds, and soil and water on farmland
  - Monitoring transgenic agricultural and organic production
  - Pilot agricultural and forestry plots (tree species resilient to climate change)
  - Green roofs and Certification Program for Sustainable Buildings (both offer tax incentives for domestic use)

Prioritization of projects

- Identification of projects made using the early warning system and climate modeling

SOURCE: Written response from city administration

SLIDE 319



B High level of coordination between agencies

Responsible organization

- In 2010, the Interagency Commission on Climate Change was created
- The commission consists of 36 public agencies and is the governing body that defines and proposes measures to adapt to climate change

Levels of authority

- The main adaptation responsibilities related to early warning system are:
  - Early Warning System (hydro-meteorological forecast for the Valley of Mexico): **Ministry for Civil Protection, Directorate General for Prevention**
  - Management of watersheds: **Ministry of Environment, Directorate General of Reforestation, Parks and Cycle Paths**
  - Protection and recovery of crops and native flora: **Ministry of Rural Development and Equity for Communities, Directorate General of Rural Development**
  - Remote sensing and monitoring of forest fires: **Ministry of the Environment, Directorate General of Natural Resources Commission**
  - Monitoring epidemiologic climate change: **Ministry of Health**
  - Care for people vulnerable to extreme weather events: **Institute of Assistance and Social Integration of the Federal District (IASIS)**

Coordination of departments

- Intra- or inter-institutional linkages, on the basis of civil protection system, of various government areas (environment, civil protection, health, rural development, water systems) as they are all have functions related to social adaptive capacity

SOURCE: Written response from city administration