

# Climate resilient Zhuhai: Flood defence approach recommendations

May 2020

Mark Broos, Kasper Spaan, Marcel van der Meijs, Willemijn van Mossevelde



Europe-China Eco-Cities Link  
中欧低碳生态城市合作项目



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## Preface

In 2018, under the request of Zhuhai Housing and Urban Planning Development, a team of Dutch experts from Amsterdam and Rotterdam, selected by the Europe-China Eco-Cities Link (EC-Link) project, supported with the revision of the Zhuhai Urban Planning & Technical Standard and Guideline, which is the overall guideline for urban planning and city development in Zhuhai. The support especially focused on flood prevention and rain proof measures, with the aim to not only advice on an overall strategy and policy to guide resilient city development, but also increase the awareness of Zhuhai's citizens.

In 2019, the EC-Link Project team, together with Dutch experts were in Zhuhai to give workshops and presentations on resilient city development within the framework of the revision of the Zhuhai Urban Planning and Technical Standard and Guidelines. The workshops were extremely important to allow European and Chinese experts to exchange knowledge and information to allow the EC-Link Project to effectively support Zhuhai municipality in its process to build an effective resilient city.

This paper, giving an overall strategy and policy direction on flood prevention, is the outcome of this process. It provides specific flood defence recommendations, complemented with an intervention toolbox, which will guide Zhuhai's future sustainable coastal development.

The Dutch expert team consists of a climate adaptation expert and a flood protection expert from Waternet and an urban planner from Palmbout Urban Landscape.

Waternet is the only water company in the Netherlands that covers the whole water cycle, providing safe, clean and sufficient supply of water. World Waternet was founded to help combat global water challenges. The foundation offers sustainable, integral solutions to worldwide water issues.

Palmbout Urban Landscapes produces spatial designs for the domains of urban planning, landscape and exterior space. Generating visual images is the quintessence of their design approach. They visualize both the embedment of the project in the larger scale of city and landscape, and its elaboration in terms of typology, details and materials.

# Content

PREFACE	4
1. INTRODUCTION	
1.1 BACKGROUND	6
1.2 TIMELINE OF THE ZHUHAI EC-LINK PROJECT ACTIVITIES	8
1.3 SUMMARY OF FINDINGS	9
2. THE DUTCH APPROACH TO FLOOD PROTECTION	
2.1 THE DUTCH DELTA PROGRAM	10
2.2 THE "ANALYSIS, AMBITION, ACTION" METHODOLOGY	10
2.3 SAFETY CHAIN APPROACH IN FLOOD RISK MANAGEMENT	11
2.4 ADAPTABILITY IS KEY TO 'GOVERNING THE UNKNOWN'	12
2.5 A DESIGN-LED APPROACH INTEGRATES A BROAD SPECTRUM OF NEEDS	13
3. FLOOD DEFENCE POLICY RECOMMENDATIONS FOR ZHUHAI	
3.1 ANALYSIS: VULNERABILITIES AND OPPORTUNITIES OF ZHUHAI	14
3.2 AMBITION: GOALS TO BE ACHIEVED FOR A RESILIENT ZHUHAI	15
3.3 ACTION: INTEGRAL DESIGN, PARTICIPATION AND REALISATION	15
4. TOOLBOX FOR ZHUHAI	
4.1 HOW TO USE THE TOOLBOX	16
4.2 ZHUHAI, URBAN LANDSCAPE EXPLAINED	18
4.3 THE TOOLBOX	20
4.4 TOOLBOX FOR LOVERS ROAD, CENTRAL DISTRICT	22
4.5 TOOLBOX FOR JITIMEN RIVER	34
5. FINAL RECOMMENDATIONS	42
6. FINAL NOTE	43
COLOFON	

# 1. Introduction

## 1.1 Background

Zhuhai, one of EC-Link' Project's pilot cities is a fast growing coastal city. It has experienced significant growth and unprecedented land-use changes in the last three decades. Parts of Zhuhai are originated from sediment landing of the Pearl River estuary. With a coastline stretching 690 km and under the influence of tropical typhoons during summer, the city is exposed to high risks of extreme weather disasters such as typhoon, heavy rainstorm and floods.

Most parts of the coastline are provided with a flood defence system, protecting Zhuhai from flooding from the ocean and rivers during storm conditions. The city of Zhuhai is growing and new areas are under development. These new areas need a sufficient flood protection system.

Most of the existing flood defence systems are built in a traditional way. The constructions are designed as a concrete wall which are part of footpaths and/or roads. During recent typhoon landings, great damage was suffered in some parts of Zhuhai. The damage was caused by flooding from heavy rainfall and flooding from the ocean and rivers. The traditional flood defence system was at some parts not high enough. This caused overtopping and in some cases flooding.

The Netherlands is known for its knowledge and expertise in the field of flood protection and the country is renowned for its integrated approach. An integrated approach involves a radical transformation of the way that we think about change. From something that we simply respond to and objectively manage, to something that we consciously create.



# 1. Introduction

## 1.2 Time line Zhuhai EC-link project activities

### JUNE 2018

- Introduction visit: reflection on policy documents and discussion for further cooperation.
- Lecture and presentation on strategy and cases in the Netherlands for resilient city development.

### DECEMBER 2018

- Presentation of the Dutch approach for climate resilience, including examples of measures in Rotterdam and Amsterdam.
- Presentation of first findings on Zhuhai's challenges.

### MARCH 2019

- Consulting report for guidelines, principles and process for a resilient Zhuhai. This report showcases the European approach and shares new findings in the form of strategies and case studies.

### MAY 2019

- Pilot 1 report: Qianhuan area resilient design suggestions for green belt park and surroundings.
- Pilot 2 report: Zhuhai - Resilient and liveable city, public participation for resilient city building.

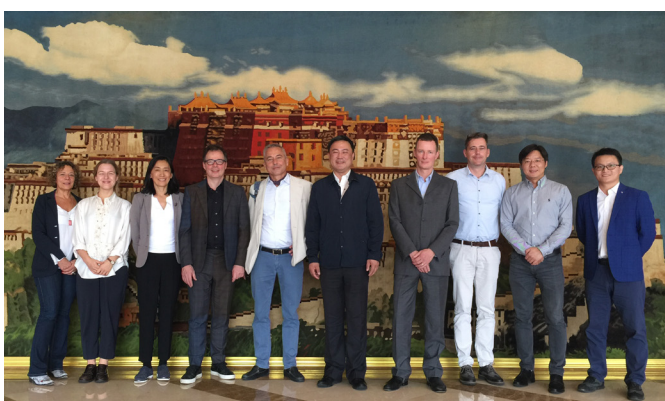
### NOVEMBER 2019

- Three-day workshop and training on climate adaptation, and flood risk and water management.
- Paper with flood protection policy recommendations.

In 2018, the support for the revision of the Zhuhai Urban Planning & Technical Standard and Guideline especially focused on flood prevention and rain proof measures, with the aim to not only advice on an overall strategy and policy to guide resilient city development, but also increase the awareness of Zhuhai's citizens. At the end of 2018, three pilot projects were selected to be carried out regarding urban planning and climate resilience:

1. Resilient city design for Qianhuan area green belt area
2. Public participation and urban design for public space in old city neighbourhoods
3. Integrated approach for climate resilient coastal stretches

In May 2019 the Dutch expert team visited Qianhuan park at three locations, followed by a workshop with the representatives of the Zhuhai Urban Planning & Design Institute. In addition, four locations in Xiangzhou district, Shishan neighbourhood were selected for public participation, with the aim to revitalize the locations with the concept of resilient city development.

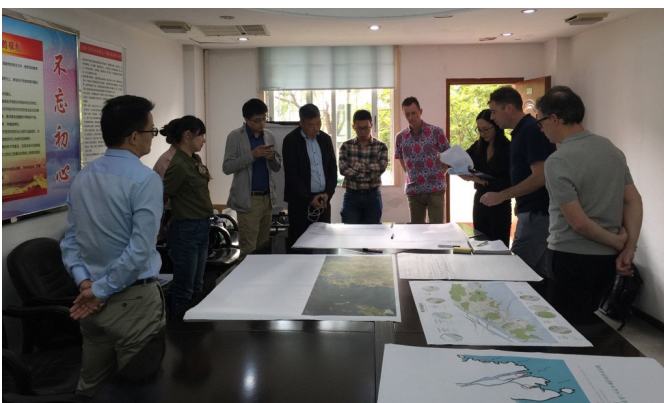




Pilot 1 and 2 were successfully finalized during visits in March and May 2019. For pilot 3, a work visit was planned in November 2019. To advise on a sustainable flood defence system and how to create public support, a three-day workshop was carried out. The Dutch expert team assessed the best conditions to allow Zhuhai to apply integrated planning for newly developed areas (Hengqing & Jinwan coast areas), but also in existing areas where the current water protection level is insufficient (designated stretches of Lover's road). Interrelations between stakeholders and possible participants were mapped and discussed. In June 2020, a final presentation and dissemination of all findings of the 3 pilot projects and consulting report is planned.

### 1.3 Summary of findings

In Zhuhai, the urban development planning process involves various ministries and departments. These different parties seem to work independently of one another with limited attention to water safety conditions. The concept of climate resilient flood defences in particular is not staged as a precondition. The result is a lack of integration due to opposing ambitions, hindering coherent sustainable growth processes in the city. A more integrated flood management approach whereby the interests of stakeholders are respected is essential for Zhuhai. This will not only make Lover's Road, but the entire coastline and the urban landscape of Zhuhai, more adaptable to changing social, hydrological, and environmental conditions.



## 2. The Dutch approach to flood protection

### 2.2 The “Analysis, Ambition, Action” methodology

The Netherlands is a low-lying delta formed by the outflow of three major rivers. 26% of the country is situated below sea level, and 59% is vulnerable to flooding. The country is faced with the major, long-term tasking of redesigning many locations in order to reduce the increasing damage by flooding.

#### 2.1 The Dutch Delta Program

To combat these challenges, a joint ambition to design the country in a climate-proof and water-resilient manner, was set down in a national program by municipalities, district water boards, provinces and the central government. A long-term strategy, based on a preventive and adaptive approach. The program has the following comprehensive goals:

- Increase the production rate of flood protection projects
- Improve efficiency of flood management by reducing the costs per kilometre
- Enhance the societal value of flood protection projects
- Improve the cooperation between the authorities involved
- Encourage integration of taskings and participation by stakeholders (non-governmental bodies and residents)
- Assure the quality and control of both the program and the projects

The program features concrete actions and goals for the responsible authorities. These authorities largely follow the same time schedule, with the analysis, ambition, action methodology steps.

Flood risk management is based on analysis. Authorities analyse the vulnerabilities and water-resilience of their environment with emphasis on vital infrastructure, invested assets (industry) and the physical urban environment. They translate the results of this analysis into a broadly supported ambition featuring concrete goals. This ambition is embedded in policy and legislation with a view to its implementation to manage or reduce flood risks (Figure 1)

For a good flood risk analysis it is important to accurately determine the probability of failure (e.g. using flood defence failure mechanisms, Figure 2). Especially in coastal and delta areas, continuously monitoring the condition of levees is crucial.

The ambition that is set for each flood defence system is based on an accepted failure frequency. This is a fixed rule through national and regional policies, to be implemented in a local setting. The action that is required depends on the scoping in the analysis. Which failure mechanism is dominant in the reduced safety? For each failure mechanism specific measures can be introduced.

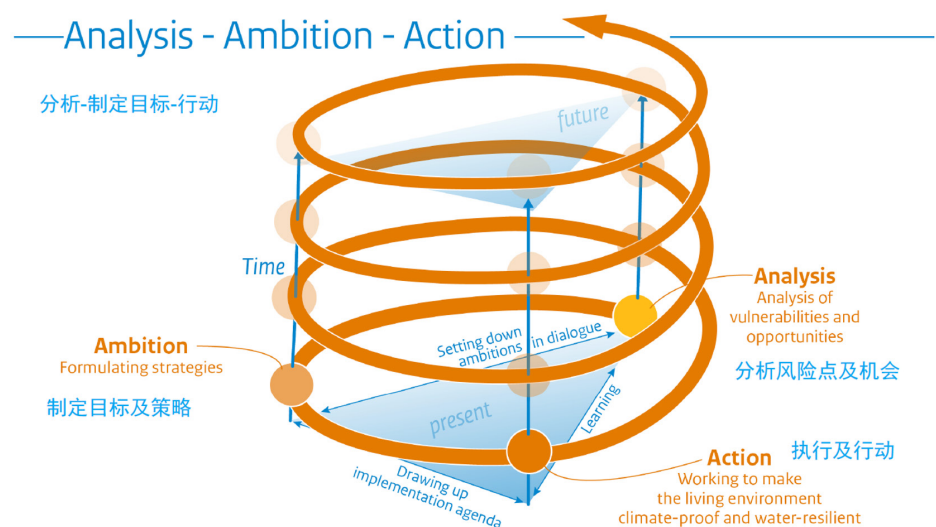


Figure 1: Methodology of the long-term, systematic address of water logging, heat stress, drought, and the impact of coastal and urban flooding (Dutch Delta Program).

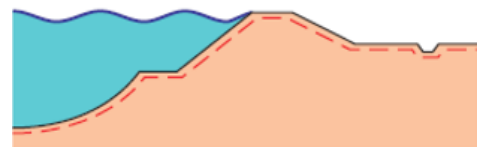
### 2.3 Safety chain approach in flood risk management

To protect the country, the Dutch have put a strong emphasis on prevention in their flood risk management policy. The so-called safety chain approach is used to continuously evaluate and, where necessary, adjust flood risk management policy (Figure 3).

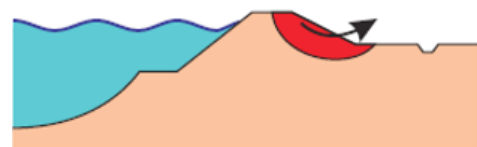
Standards are based on safety of the hinterland, costs of reinforcement and possible victims in the event of a flood. They ensure a 'basic protection level' for everyone in the Netherlands. All flood risk management tasks and activities can be deducted from the safety standard to which flood defences must comply.

The complete cycle is run every six to twelve years. If a flood defence does not meet the safety requirements after testing, a reinforcement plan is prepared together with all relevant stakeholders. This allows for wishes with regard to multifunctionality, climate change and new technologies to be taken into account. Such a plan can be set up and financed by the Dutch Delta Program.

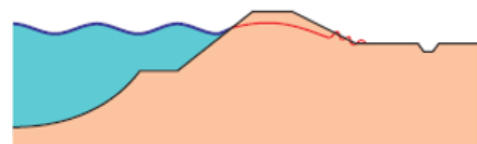
Inspections of flood defences take place every year and maintenance work is planned on the basis of this data. Excellent data management and expert staff are important conditions for future-proof management and maintenance.



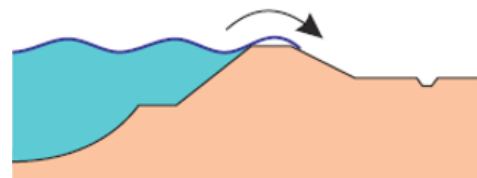
**Overflow**



**Sliding inner slope**



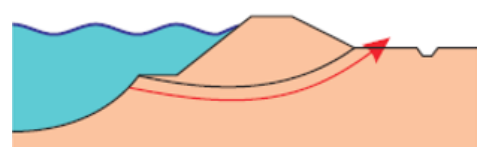
**Micro-instability**



**Overtopping**



**Sliding outer slope**



**Piping**

Figure 2: Examples of failure mechanisms of levees.

## 2. The Dutch approach to flood protection

### 2.4 Adaptability is key to 'governing the unknown'

A flood defence system requires continuous monitoring and testing at the set safety levels. These safety levels may change over time due to climate change (sea level rise, increased typhoon strength and frequency, increased riverine discharges) or spatial development with an increase of economic value and increased safety standards. A more integrative and adaptable approach accepts uncertainties. The adaptability of the flood defences is essential to respond appropriately to changing environmental or climatological conditions. It is prerequisite for future investments and therefore essential in making robust choices for levee design.

Examples where concrete walls are heightened aren't judged as sustainable solutions. Proceeding with a new round of elevations in that type of measure is hardly feasible. A robust flood defence measure is adaptable in many ways (seaward, landward, strengthening by rocks). This will save investments over time. Adaptability should be a key element in the design of the (combination of) flood defence systems.

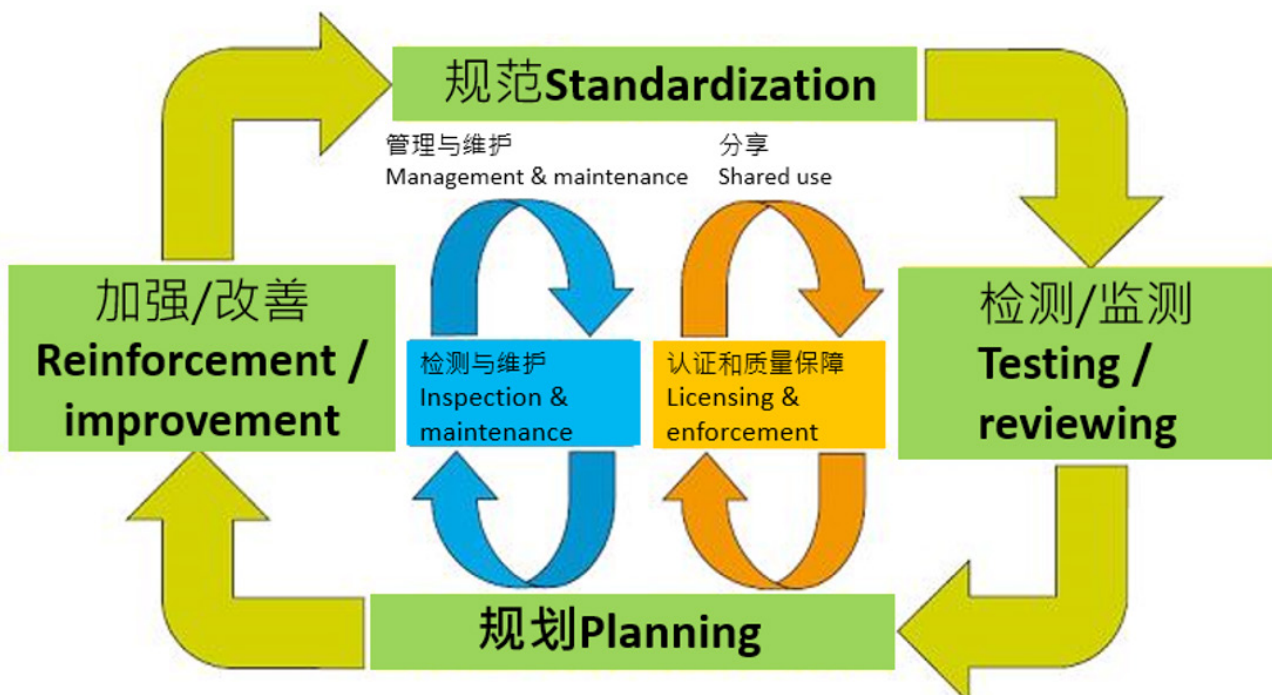


Figure 3: Safety chain approach in Dutch flood risk management.

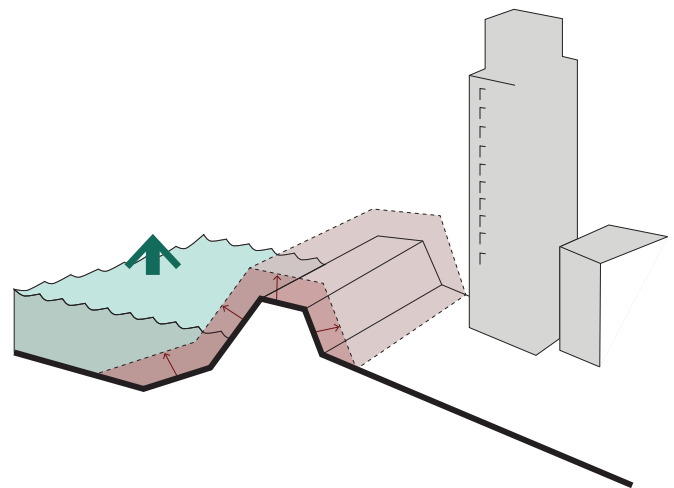
## 2.5 A design-led approach integrates a broad spectrum of needs

For climate resiliency there is no single solution, it will consist of a set of measures reducing flood risk. Different geographical conditions ask for a different set of solutions. As part of our report for Zhuhai we developed a preliminary toolbox which deals problematics concerning water into two conditions; coastal and riverine.

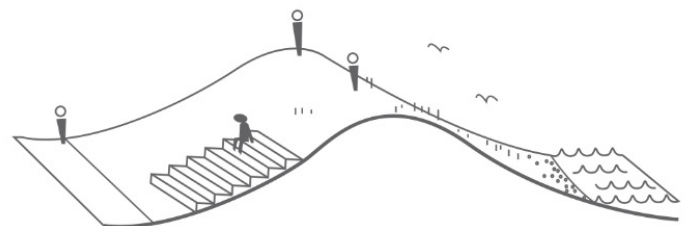
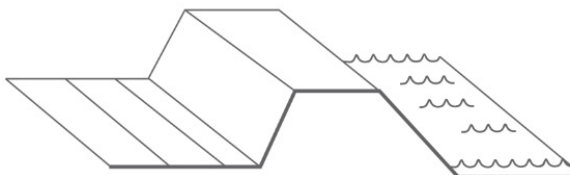
### DESIGN LED APPROACH

A design-led approach integrates a broad spectrum of needs such as biodiversity, urban planning, agricultural development and public realm, and combines them with the requirements of an area, location or region. Combining these different fields of expertise with flood defence management processes, leads to an innovative approach to flood protection. The following benefits can be achieved using the design-led approach:

- Higher quality spatial solutions
- Environmentally-sustainable solutions
- Integrated adaptability
- Cost benefits
- Higher level of collaboration with stakeholders
- Societal benefits



Adaptability: Reservation of a zone that provides possibilities to adapt to changing needs for flood safety.



Left: levee providing flood safety without additional benefits.

Right: A design led approach integrates flood safety with other opportunities. This leads to a multifunctional dike system with, next to flood safety, multiple uses providing views and ecological benefits.

# 3. Flood defence policy recommendations for Zhuhai

To apply the methodology and approach described in Chapter 2, several recommendations are made for Zhuhai. The recommendations are clustered in the three steps of the methodology: analysis, ambition, action.

## 3.1 Analysis: Vulnerabilities and opportunities of Zhuhai

### DATA MANAGEMENT: ESSENTIAL FOR HIGH QUALITY ANALYSIS

Flood defence management requires repetitive analysis. The quality (and quantity) of the available data is relevant to create a high-quality analysis. The process of collecting, storing and combining data on flood defences and damage figures is a key element in drawing up a flood defence strategy. This process should be transparent and aligned to the various governmental departments involved (local, regional and national). In this way they can share the relevant data with each other and use it to ensure water safety through high-quality analysis.

The damage caused by the latest typhoons was not clear in detail. Visible effects were flooded areas, but the failure mechanisms caused the floods were less clear. A clear and detailed overview of the damage helps to determine where the most urgent tasks for levee reinforcements should be carried out. In addition, this data it is essential to achieve a good cost benefit.

### CLIMATE CHANGE SCENARIO'S

Climate change increases the uncertainty within which water safety decisions must be made and how to look ahead. Climate scenarios can be applied to expectations about the scale and rate of climate change and the subsequent safety challenges resulting in matching ambitions. When making decisions about levee reinforcements, the latest insights into the effects of climate change must be taken into account. Due to the availability of new scenarios, there is a risk that decision-making will be halted due to uncertainties.

One of the principles for climate adaptation is making flood defence systems robust and/or flexibly adaptable. A robust water defence is resistant to extreme events and meets several possible future climate scenarios. Flexible measures make it is possible to respond to the scale and speed of climate change. Sufficient space must be reserved for future levee reinforcement, because the availability of space is often less flexible. Physical structures, such as concrete dams or storm surge barriers, generally have less flexibility because the design and execution must be chosen once for a specific size. The lifespan of the measure is then important for the degree of climate change to be taken into account.

### RISK ANALYSIS

Good asset management means that the safety requirements and ensuring the necessary preventive management and maintenance are implemented through risk analyses. The operators must therefore regularly inspect the flood defences, including non-water retaining objects that can have consequences for water safety, to assess whether the physical condition of the barrier still meets the (design) requirements. If the physical condition of the barrier no longer meets these requirements due to technical ageing or (storm) damage, the stated ambition falls short and action must be taken. With high-quality models, the future stress on the flood defences can be scanned.

### 3.2 Ambition: goals to be achieved for a resilient Zhuhai

#### MAKE DECISIONS BASED ON AMBITIONS

In order to accelerate and intensify the realization of water-resilient and climate-proof flood defences, a clear and explicit set of ambitions must be formulated in the preparation phase. Answers to the following questions should be taken into account:

- What typhoon strength should the city be able to withstand?
- At what sea level rise should the designed flood defences cope?
- What is the accepted level of damage?
- Are secondary measures applicable to reduce damage?

The extensive and explicit set of climate resilience ambitions should reflect the responsibilities of all government authorities involved. Decisions regarding investments, urban planning and urban design can then be challenged with the set of ambitions.

#### COMBINE DATA WITH SPATIAL PLANNING AND ENVIRONMENT

Urban developments and infrastructure investments are key drivers in the economic valuation of an area. Strategic urban planning is also relevant in relation to climate stressed areas. Development in low-lying areas has for future investments and maintenance of flood defences. New infrastructure can be combined with new levee elements, thereby reducing the costs of individual levee systems. Especially crucial and vulnerable assets such as data centers, hospitals and energy hubs are considered dominant infrastructure for placement in spatially robust locations in relation to climate stressors. The ambitions of natural assets should also be taken into account, as they can be integrated into nature-based solutions for flood defence design.

#### INTEGRAL APPROACH AND FLOOD DEFENCE STRATEGY

A top-down flood defence strategy should be available to guide spatial planning towards robust and economically viable choices. Addressing climate-adaptive solutions in the urban planning system will lead to an integrated approach with lower costs for design, realization and maintenance. Ecological ambitions can also thrive in these solutions. Cost benefit analysis on the scale of the Pearl River delta can help in making distinctive choices between storm surge barriers vs more robust riverine levee systems.

#### STAKEHOLDER INVOLVEMENT AT EARLY STAGE

With a proactive approach to other stakeholders, their interests and ideas can find a place in the design and development process around levee design and flood defence restructuring. It can help reduce initial resistance to changes in the urban landscape. In addition, an awareness programme on flood defences and climate adaptation can create a committed urban population.

### 3.3 Action: integral design, participation and realisation

#### INTEGRATION OF CHALLENGES FOR OPTIMAL SOLUTIONS

The rural and urban fabric of the city of Zhuhai is unique. Each part of the city is developed over time and under certain conditions. Liveability and landscape aesthetics have always been important elements in the development of the urban landscape. The challenge that reinforcing the flood defence systems brings to the urban fabric and local surroundings can only be tackled with the integrated design-led approach. This way, all the stakeholders, issues and ambitions can find each other in local situations. Made-to-measure is key in this design-led approach to find the optimal solutions. The toolbox that is introduced helps bring together challenges and solutions, and shows different design perspectives.

#### PARTICIPATION

Ambitions often call for active and broad-based participation within society, primarily at the local level. It is therefore recommended to involve businesses, NGOs, knowledge institutes, educational institutions, and residents in the implementation of new plans.

#### REALIZATION

By using a design-led approach, it is possible to combine different interests and conditions and easily identify win-win situations. For example, combining coastal protection measures with improving infrastructure, spatial quality, etc. In this way, multiple budgets can be used to create an economically feasible project.

# 4. Toolbox for Zhuhai

In order to transform the Zhuhai's coastal zone into a flood proof design, the coastal zone has been analyzed and divided into several sections based on typology. In addition, a toolbox with a selection of promising (on land and offshore) measures has been developed. The toolbox can assist in the search for flood protection solutions. The measures all have potential added value for other objectives such as climate, nature and infrastructure. They offer a new perspective and philosophy on flood protection.

## 4.1 How to use the toolbox

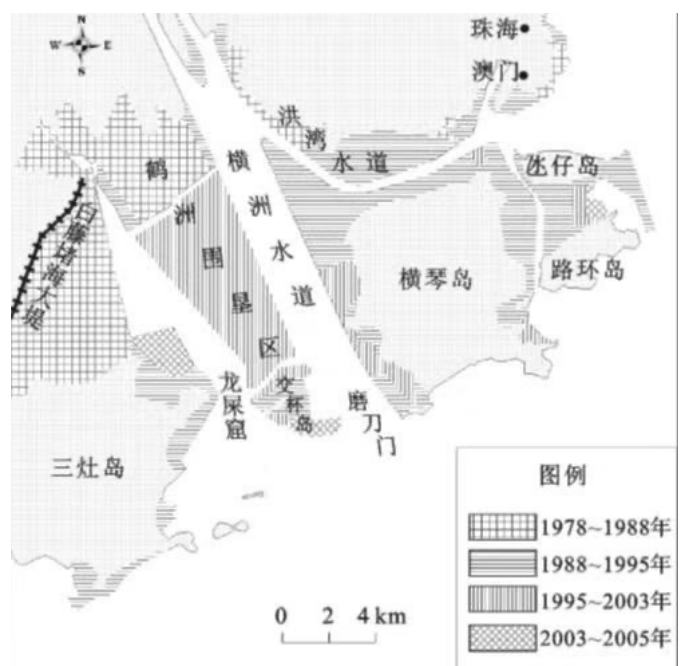
The toolbox principles are feasible in existing developments as well as in the old town of Zhuhai and in areas that are yet to be developed. For new developments it is easier to develop sustainable solutions that adapt to climate change. In the old town of Zhuhai's, the possibilities are more limited because the infrastructure is difficult to adapt. Nevertheless it is possible to reinforce the current flood defence system in a sustainable way.

Different solutions from the toolbox may be suitable for each section along the coast. Some measures are effective on their own, some measures need to be combined with others to ensure flood safety. A strong relation between the different sections in the toolbox is required to create a strong and coherent coastal flood protection with a characteristic identity. As a result, the coastal zone can contribute much more to the city than just flood protection. For example, a coherent coastal zone can function as a boulevard for pedestrians and cyclists. It can function as a place to exercise or relax while overlooking the bay. The coastal zone can become a beautiful and attractive place in the city.

A strong and coherent plan does not mean that the entire coastal zone has the same design. It means it has a strong identity that can be experienced along the coast, and in addition, functions can be added at the local level, such as sport facilities, stairs, viewpoints, etc.

In the following pages you will find subsequently:

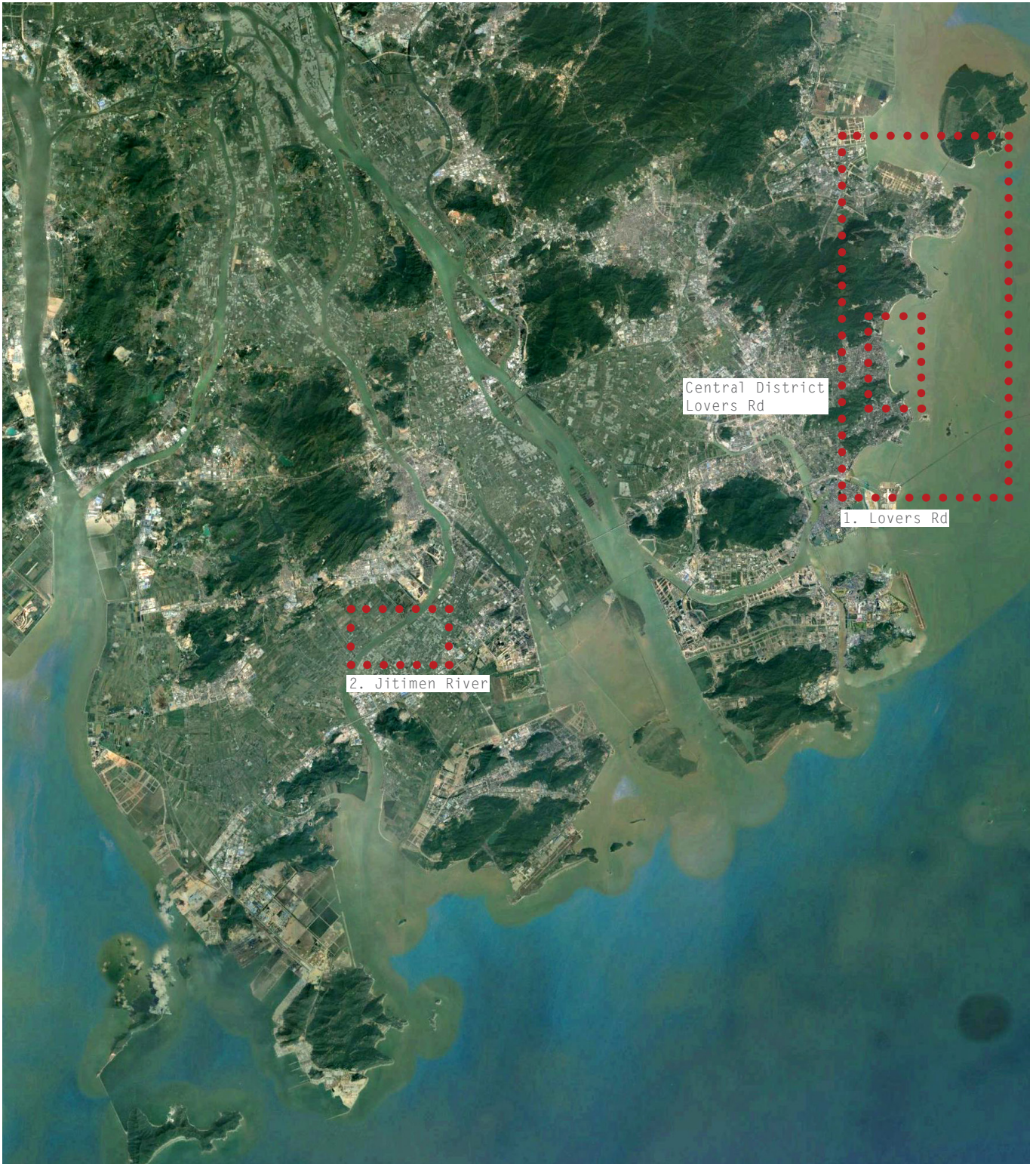
- Page 18: An overview of the Zhuhai Delta which provides a first analysis of the layers of the Zhuhai landscape (coastline, landscape, infrastructure and urbanization).
- Page 20: Different zones for flood defence. In the ocean (1), on the edge ocean and land (2), landward flood defence (3), and building with nature (4).
- From page 22: After this we zoom in on the two locations. First describing the situation, than showing solutions for flood defence in the toolbox.



In the last decades the Zhuhai delta completely changed its outline. The shallow water (due to sedimentation) made it possible to reclaim land from the sea. Transforming the dynamic delta (top figure) into a man-made border between land and ocean.

In the bottom figure the different stages of this process is shown.



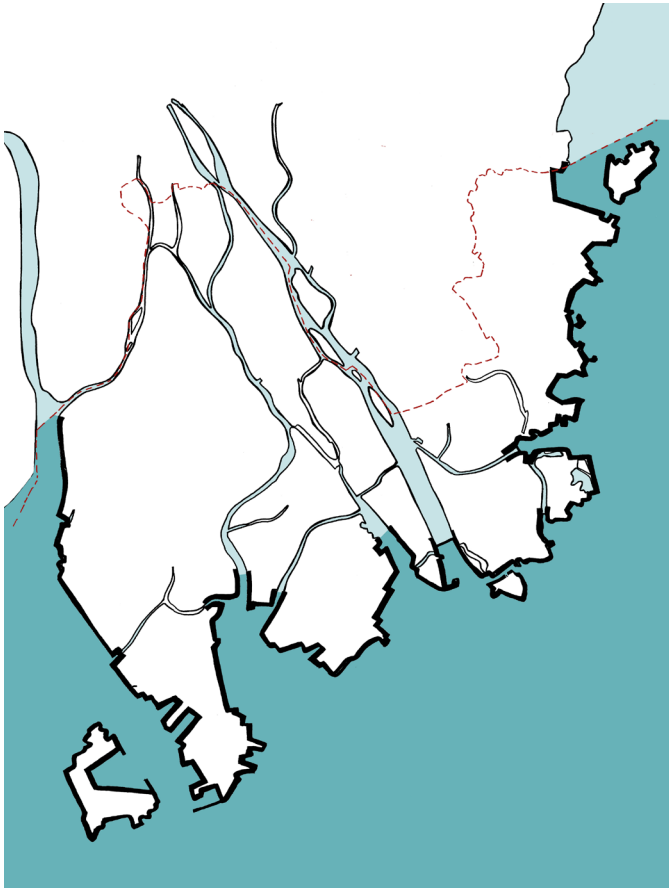


For the toolbox we looked at two significantly different conditions; coastal and riverine. The boxes mark the two locations for which the toolbox provides solutions. Lovers Rd (with the central district) is a coastal location which is vulnerable for typhoons, sea water level rise and other coastal conditions. The second box marks the Jitimen river. A riverine location which, among others, can be vulnerable for flooding due to extreme water runoff from upstream.

# 4. Toolbox for Zhuhai

## 4.2 Zhuhai, urban landscape explained

The following maps give an overview of the layers of the Zhuhai landscape.



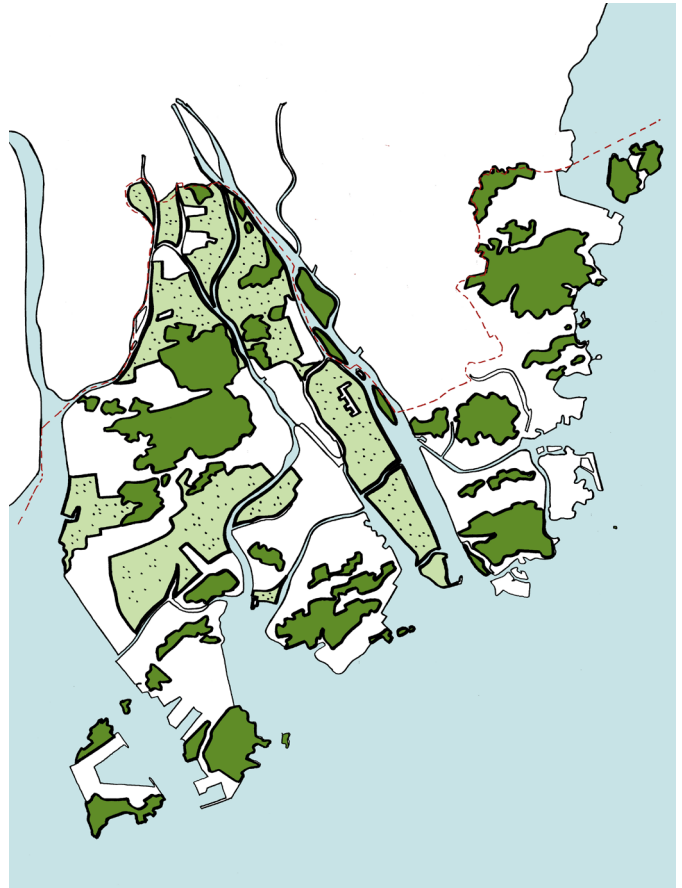
### Riverine and coastal flood protection

#### COASTAL

Protection for the coastline being directly exposed to Sea Level Rise, typhoons etc. A layered approach with a toolbox of possibilities fixating the coastline.

#### RIVERINE

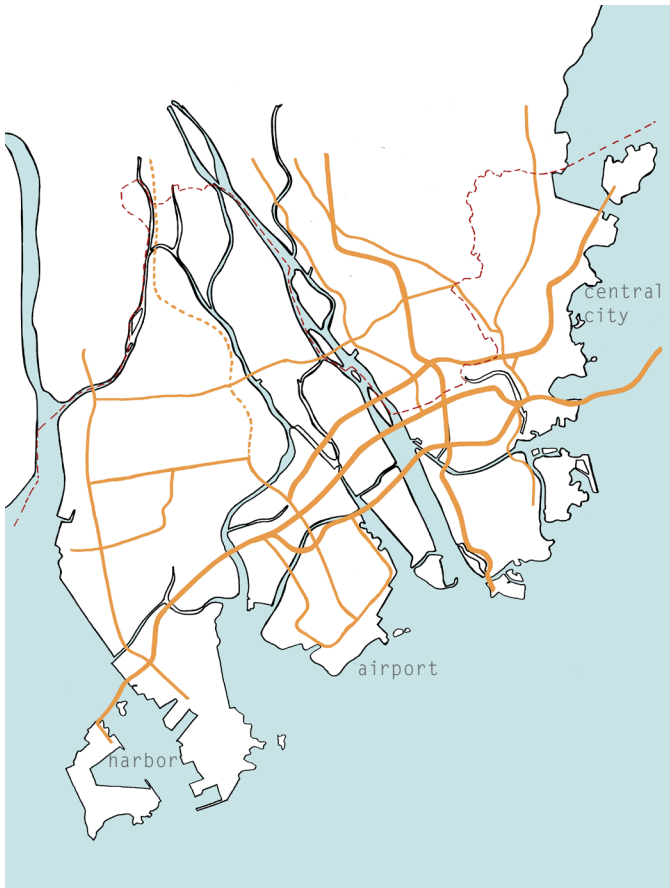
Inland levee systems that deals with sea level rise and peak river discharge. A toolbox that shows possibilities to make room for the river combining spatial quality with safety.



### Natural landscape

Zhuhai's delta is a dynamic one. The landscape is formed by sedimentation and land reclamation.

It consists of higher forested mountains on land and in the ocean which are protected (dark green). In between the mountains is lower lying land originated by years of sedimentation or manmade land reclamations (light green). Rivers divide the low lying areas into a delta landscape.



### Crossing the delta

Zhuhai's infrastructure is organized perpendicular to the natural delta system, connecting the central city with the harbour and airport.

Therefore Infrastructure crosses the river system multiple times, making it necessary to construct and uphold a big amount of bridges, dams etc. These constructions are fixed and fixate the delta.



### Urbanized Delta landscape

Zhuhai is rapidly urbanizing creating new residential areas for a growing population. New urban developments are spread across the entire delta, from the city center towards the port. This rapid urban development fixates the once so dynamic landscape. Land reclamations create new, hard boundaries to provide safety for the coming developments.

These maps are a visual interpretation of received Masterplan drawings of Zhuhai (future). They reveal a general image and are not to be interpreted as exact maps.

# 4. Toolbox for Zhuhai

## 4.3 The toolbox

Main instruments from the developed toolbox are:

### 1. WAVE ENERGY REDUCING SEAWALL

Design a wave breaker out of rocks or in the form of beach. A wave breaker reduces overtopping in storm conditions. This will allow a lower height of the flood defence system.

### 2. ELEVATION OF LAND AND INFRASTRUCTURE: REDUCTION OF OVERFLOW

To reduce overflow of seawater during a storm, existing water defences can be elevated by raising roads or boulevards or by creating flood barriers in the park or by adapting fences into flood-proof constructions. These measures have a local effect on sea view. The local effect on sea views can be mitigated by introducing special viewing points along the coast where flood risk is acceptable or non-existent.

### 3. LANDWARD DEFENCE: FLOOD RESISTANT BUILDINGS, IMPROVEMENT OF DRAINAGE CAPACITY AND UPLIFTING CRITICAL INFRASTRUCTURE

Water-resistant buildings can be realized by waterproofing entrances using (movable) constructions. This prevents flooding of parking garages and other damage to buildings. This is subject to the condition that there is a closing protocol and those responsible are warned in a timely manner to close the buildings and inform the residents and/or users within sufficient time. Added value could be the realization of extra drainage capacity.

### 4. BUILDING WITH NATURE PRINCIPLES VERSUS CIVIL ENGINEERING STRUCTURES

As an alternative to civil engineering solutions with constructions, 'building with nature' principles can be applied for reinforcement measures. This reduces the effect of overtopping and strengthens itself over time, if managed properly. Mangrove can grow, retain sludge, and can lead to additional input for water safety. The added value is that such solutions have a positive impact on water quality and nature developments.



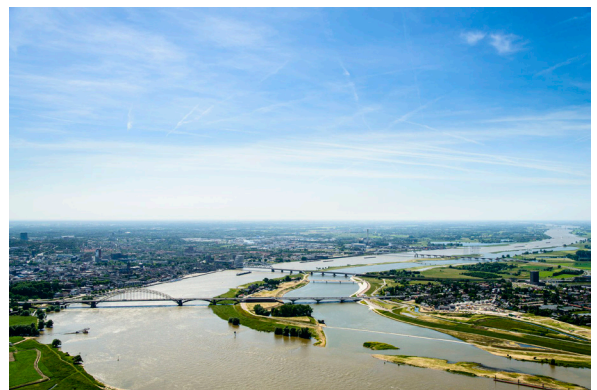
Wave breakers



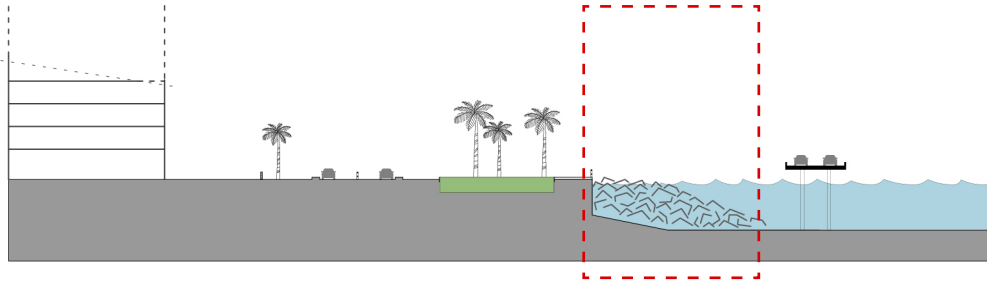
Waterfront park, New York USA



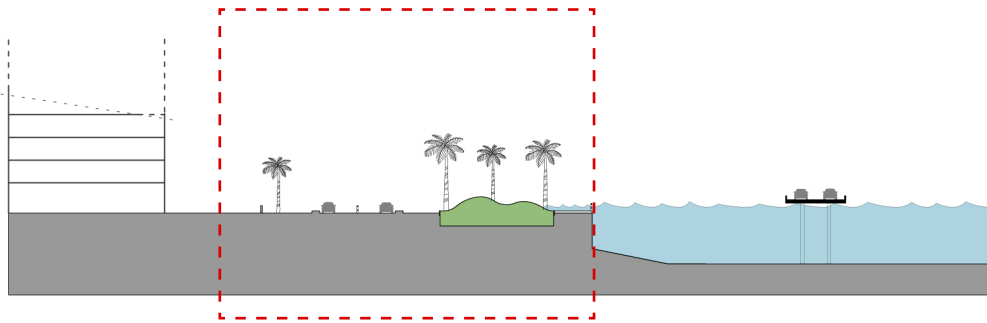
Seatable building, Hafencity Hamburg, Germany



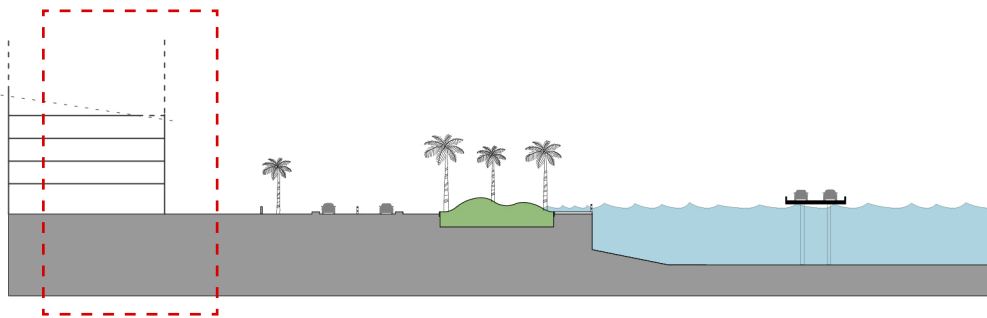
Room for the river, Nijmegen The Netherlands



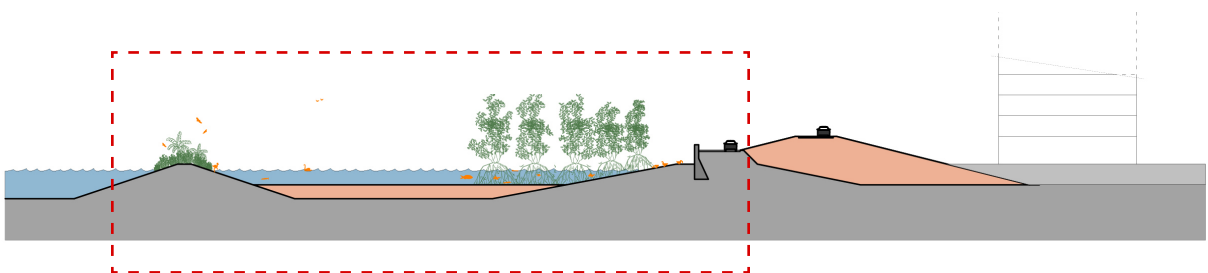
1. WAVE ENERGY REDUCING SEA WALL



2. ELEVATION OF LAND AND INFRASTRUCTURE



3. LANDWARD DEFENCE



4. BUILDING WITH NATURE

# 4. Toolbox for Zhuhai

## 4.4 Toolbox for Lovers Road, central district

Lovers Road is a scenic road that curves along the coastline of Zhuhai, offering multiple types of views of the ocean, city and mountainous landscape. Every turn on this road has its own surprise with stunning ocean, nature or city views. This combination of a composite view makes it unique and exciting.

The diversity of this 40 km long road is also reflected in the surrounding area. A great diversity of use (e.g. boulevard, beach, park) of these areas contributes to this.

During the development of Lovers Road, the road should continue to reflect this diversity. A road that gives multiple types of views remains surprising for the various passers-by; pedestrians, motorists and cyclists, and for people who use the surrounding area such as beach visitors and tourists.



Lovers Rd, Qianhuan Park



Lovers Rd, inner city

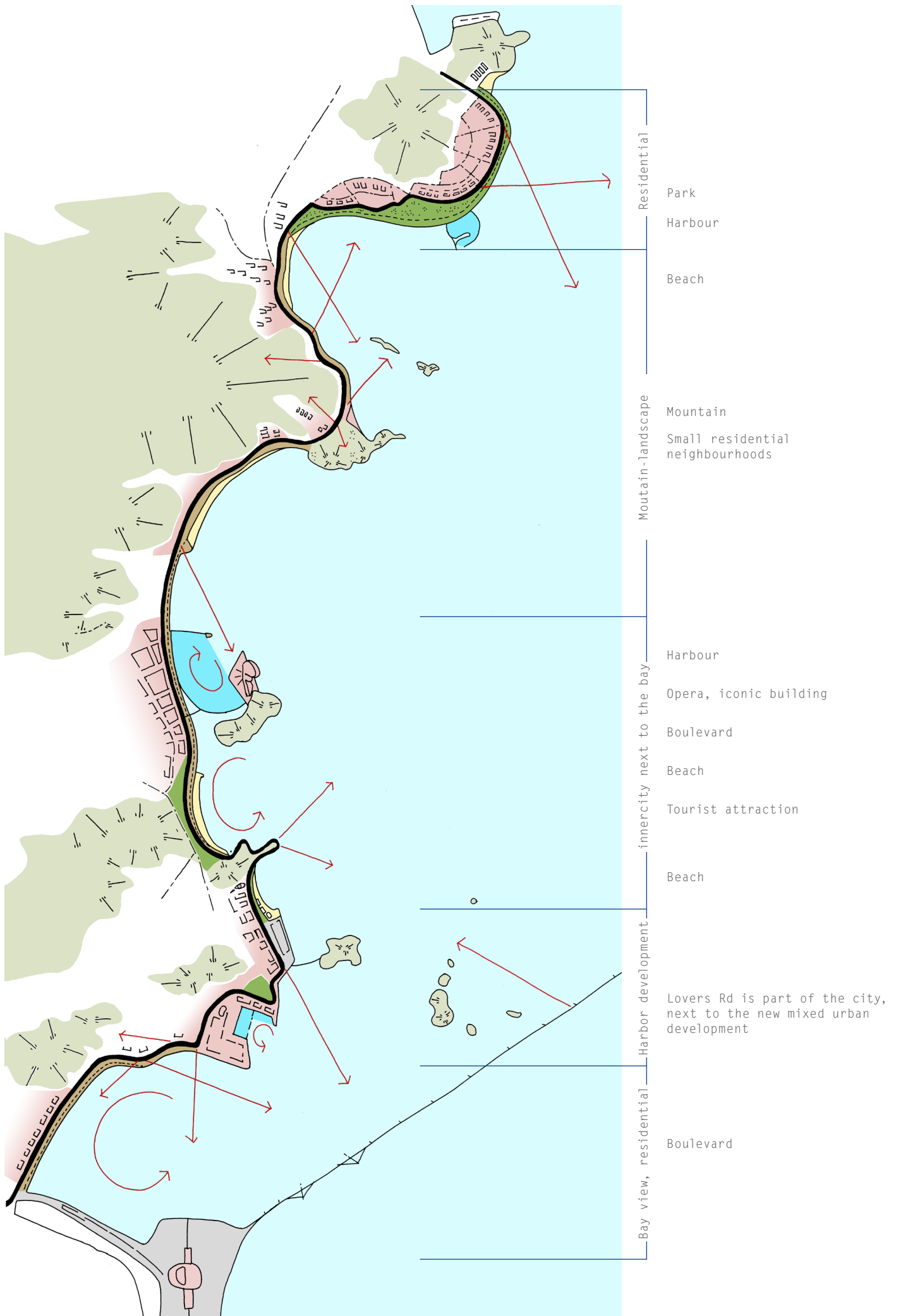


Lovers Rd, inner city



Lovers Rd, south side





Lovers Rd, a diverse, scenic coastal route of 17km inbetween the city and the bay

## 4. Toolbox for Zhuhai

### CENTRAL BAY

This is the most central part of Lovers Road with the iconic Opera House as a prominent eyecatcher. Here the coastline is formed by a hard quay next to a green, slightly elevated, park strip of approximately 45 meters wide. There is a dual carriageway next to this park strip. The park strip is used as a promenade along the ocean and as a green space for dance and individual sports. It is a well-equipped space with amenities such as coffee bars and public toilets.

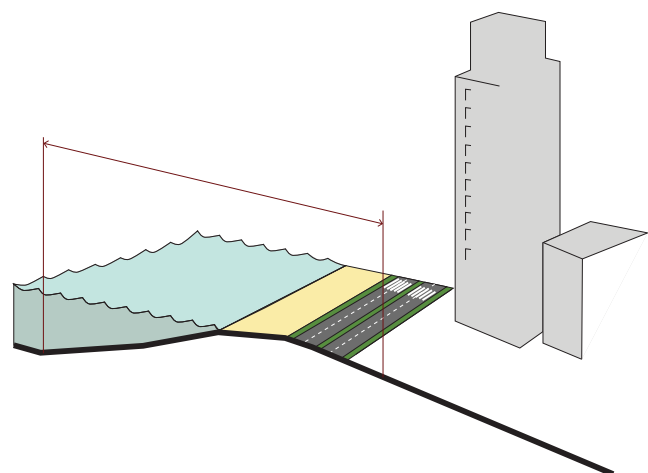
The section shown is partially adjacent to a fishing boat harbour. Within the harbour, a road leads to the Opera House.

At the Central Bay Area there is a problem with flooding when a storm occurs. During the last typhoons, parts of the area have been flooded due to overtopping of flood defences and heavy rainfall. One problem is that the water cannot drain away (too little drainage capacity and no pumping capacity). The other problem is the overtopping of flood defences that are not sustainable designed for climate change and sea level rise.

The following bottlenecks are known:

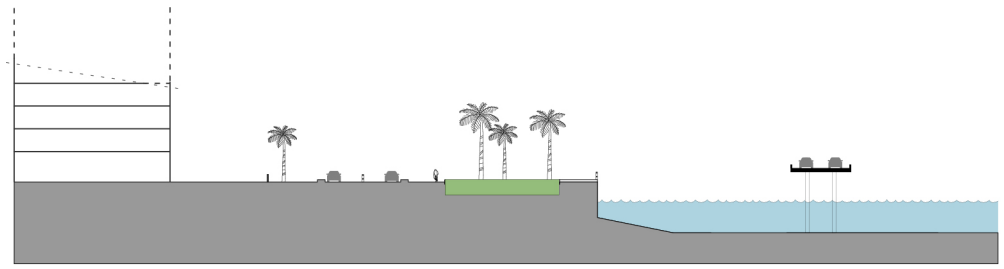
- Cooperation between the different governments is difficult
- Data is insufficient available
- Constructions are difficult to strengthen, no profile of free space available
- Scenic restrictions such as sea views from the road must be maintained

In the toolbox multiple locations in the zone between ocean and building are used to prevent flooding.

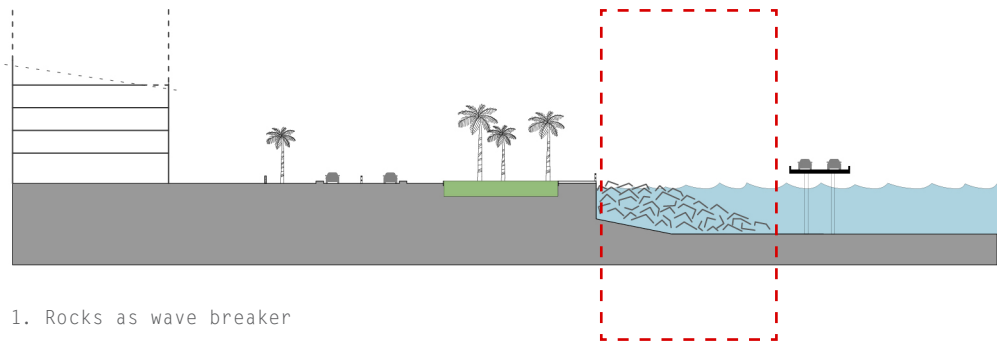


Zone inbetween building and deep water

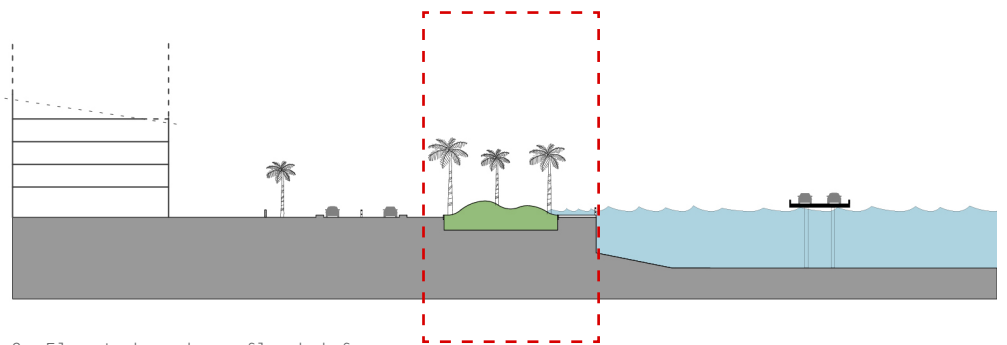




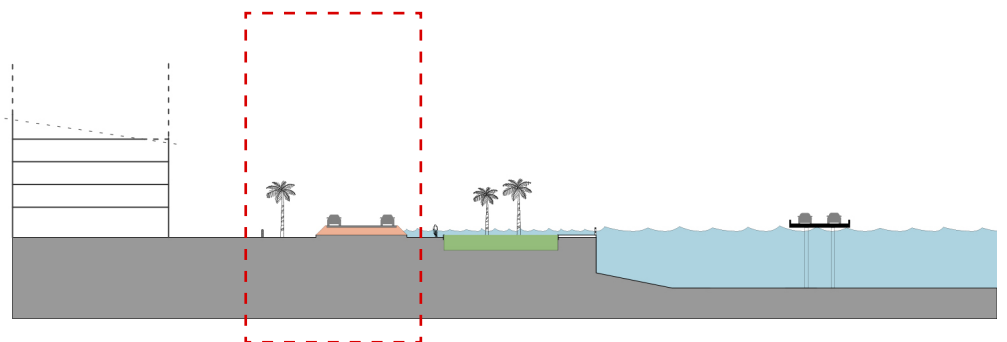
Existing situation



1. Rocks as wave breaker



2. Elevated park as flood defence



3. Elevated road as flood defence

## 4. Toolbox for Zhuhai

Toolbox for Lovers Road, central district  
coastal re-enforcement



Spatial quality combined with a flood defence, Nijmegen, The Netherlands.



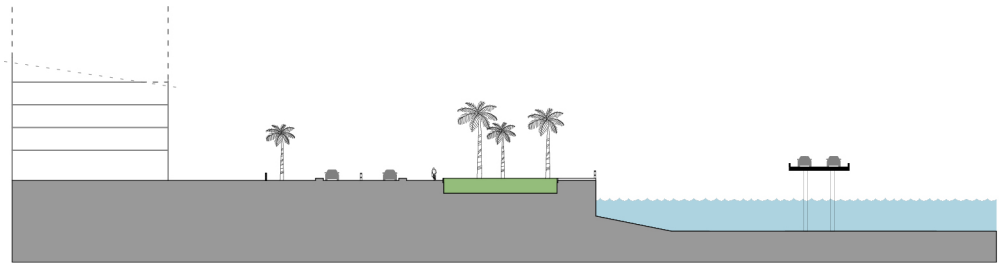
Subtile slope part of water defence, Zutphen, The Netherlands



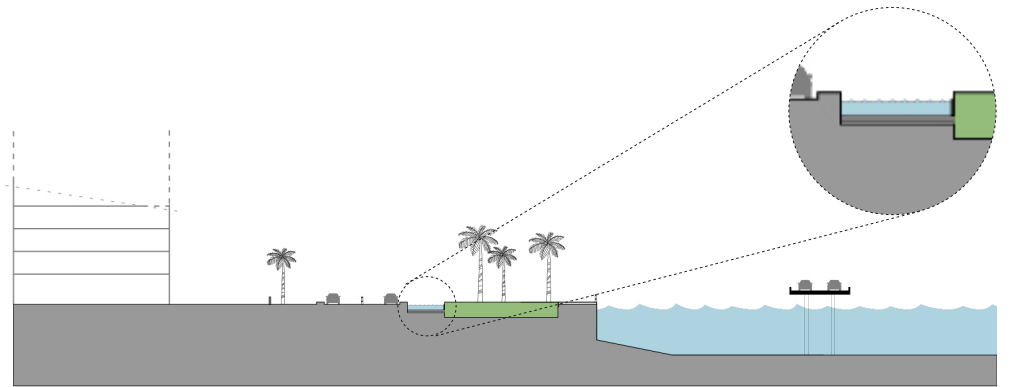
Combination of drainage and cycle path



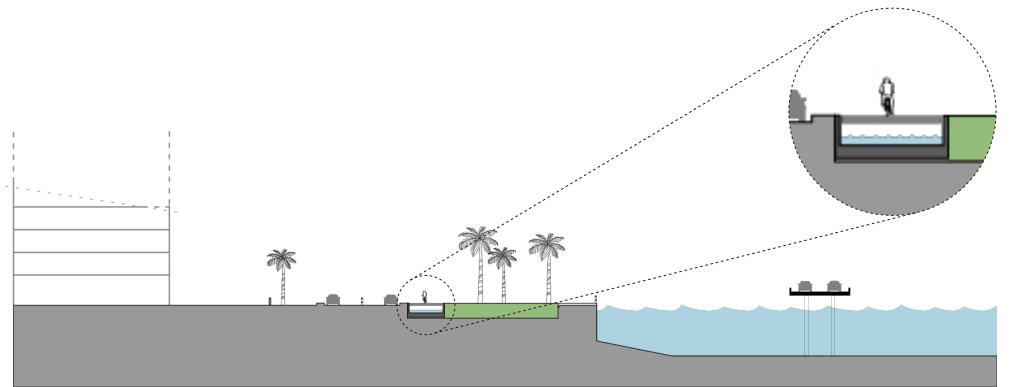
Low wall as part of the street profile and primary flooddefence. IJsselkade Zutphen



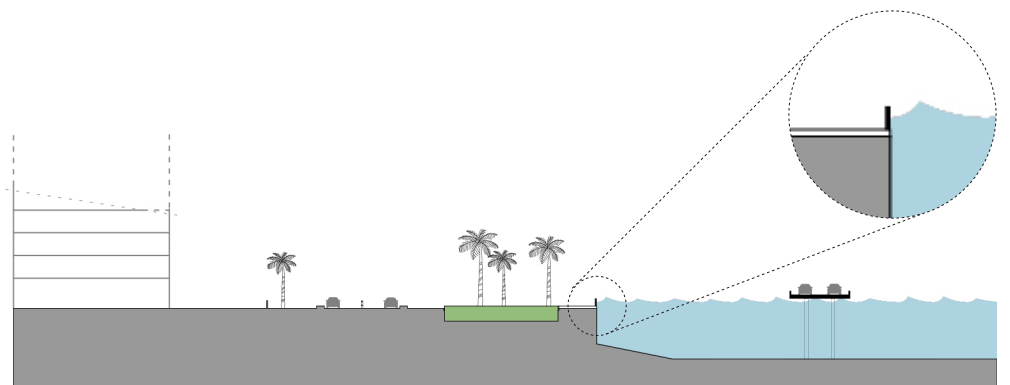
Existing situation



Lowered bicycle path as drainage canal



Double use of space: bicycle path on top of drainage canal



Coastal fence transformed into flood wall

## 4. Toolbox for Zhuhai

Toolbox for Lovers Road, central district  
coastal re-enforcement



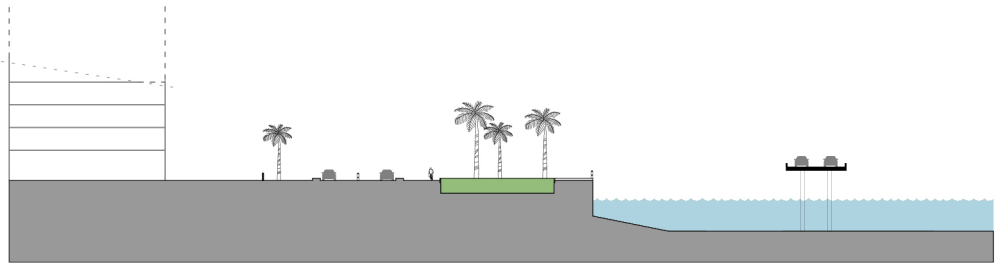
Coupure in existing walls



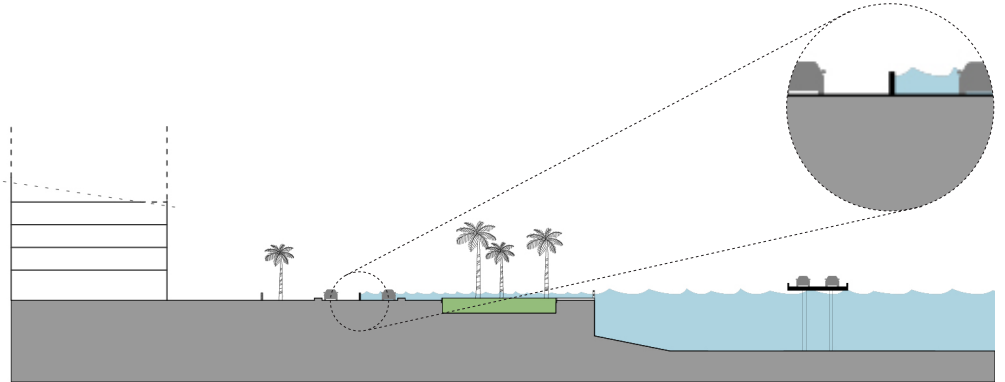
Flipable flood barrier, Wakefield (UK)



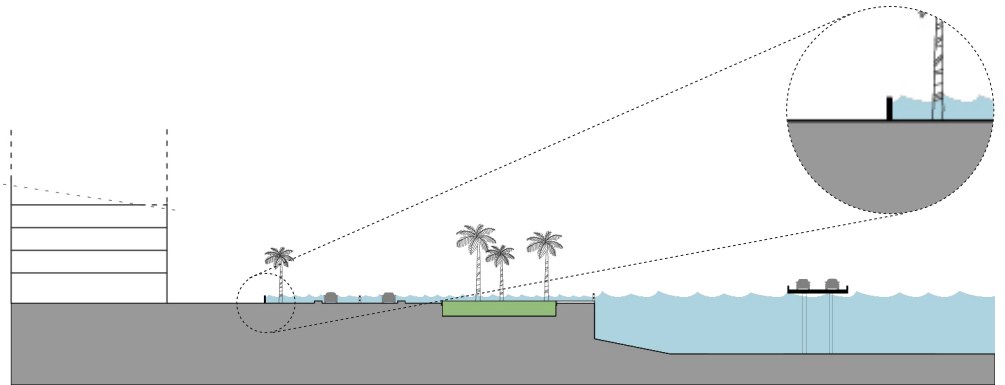
Sealable building, Hafencity Hamburg (D)



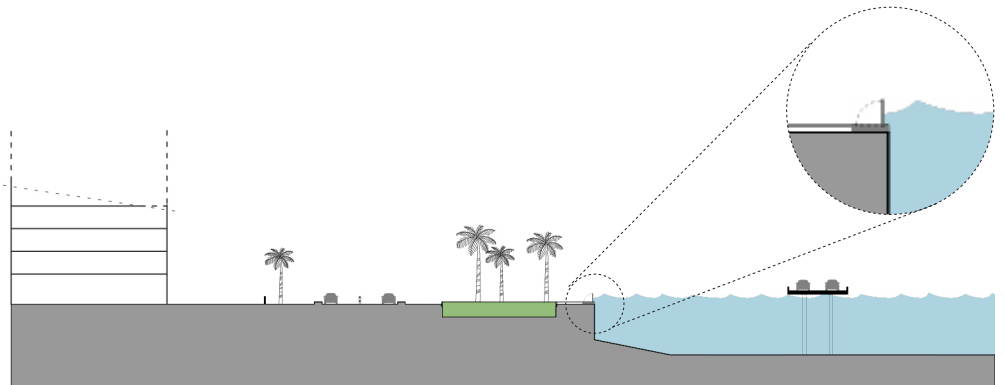
Existing situation



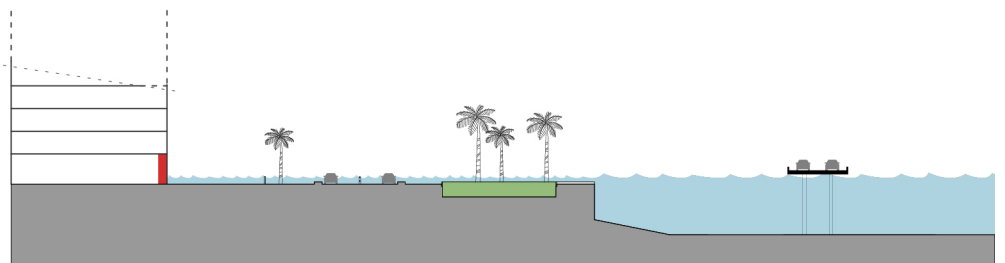
Fence on coastal road transformed into flood defence



Property boundary transformed into flood defence



Movable barrier at the coast



Flood proof building

## 4. Toolbox for Zhuhai

Toolbox for Lovers Road, central district  
coastal re-enforcement



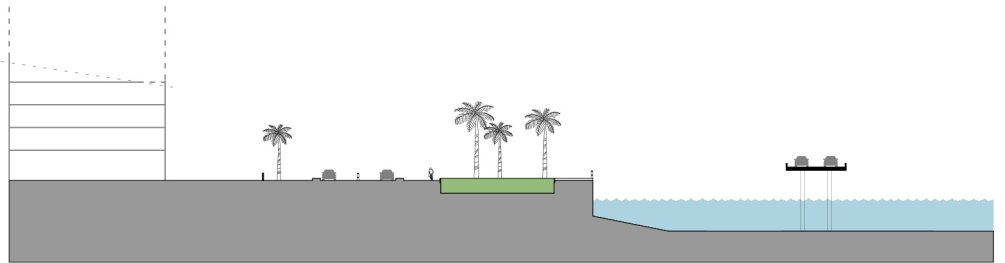
MOSE barrier Venice closed, Italy



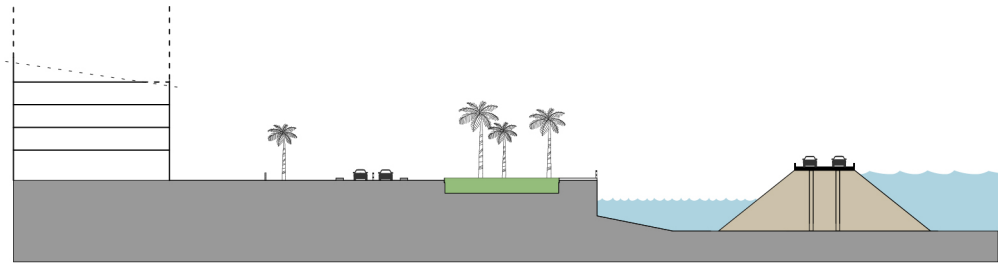
Ramspol barrier open, The Netherlands



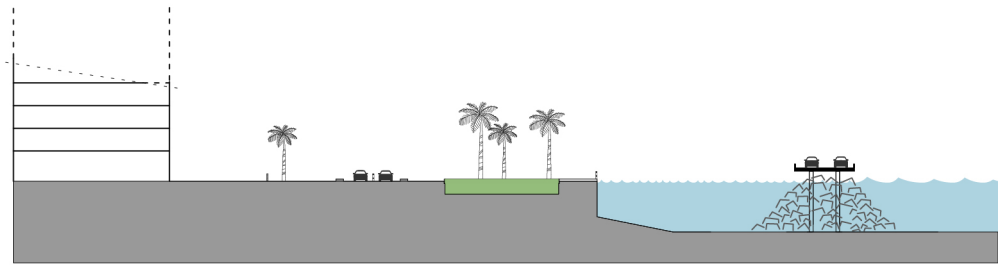
Ramspol barrier closed, The Netherlands



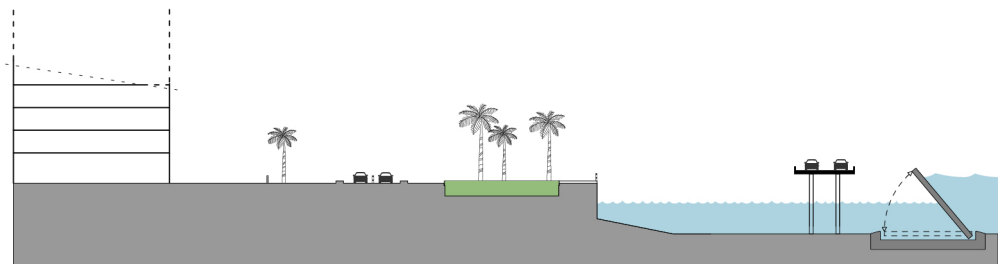
Existing situation



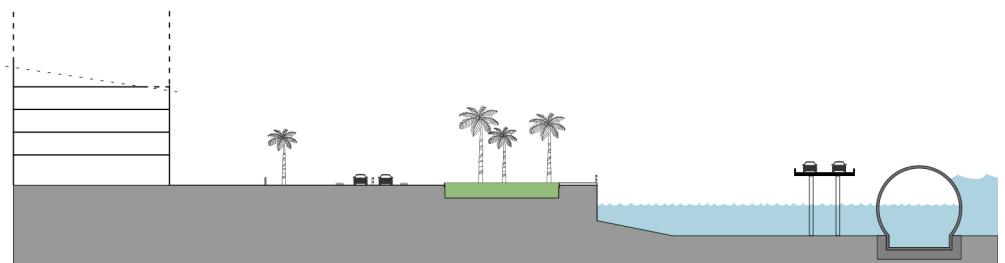
Bridge expanded to a dam



Wave breaking rocks under the bridge



Storm surge barrier (movable) in front of the bridge



Storm surge barrier (inflatable) in front of the bridge

## 4. Toolbox for Zhuhai

Toolbox for Lovers Road, central district  
coastal re-enforcement

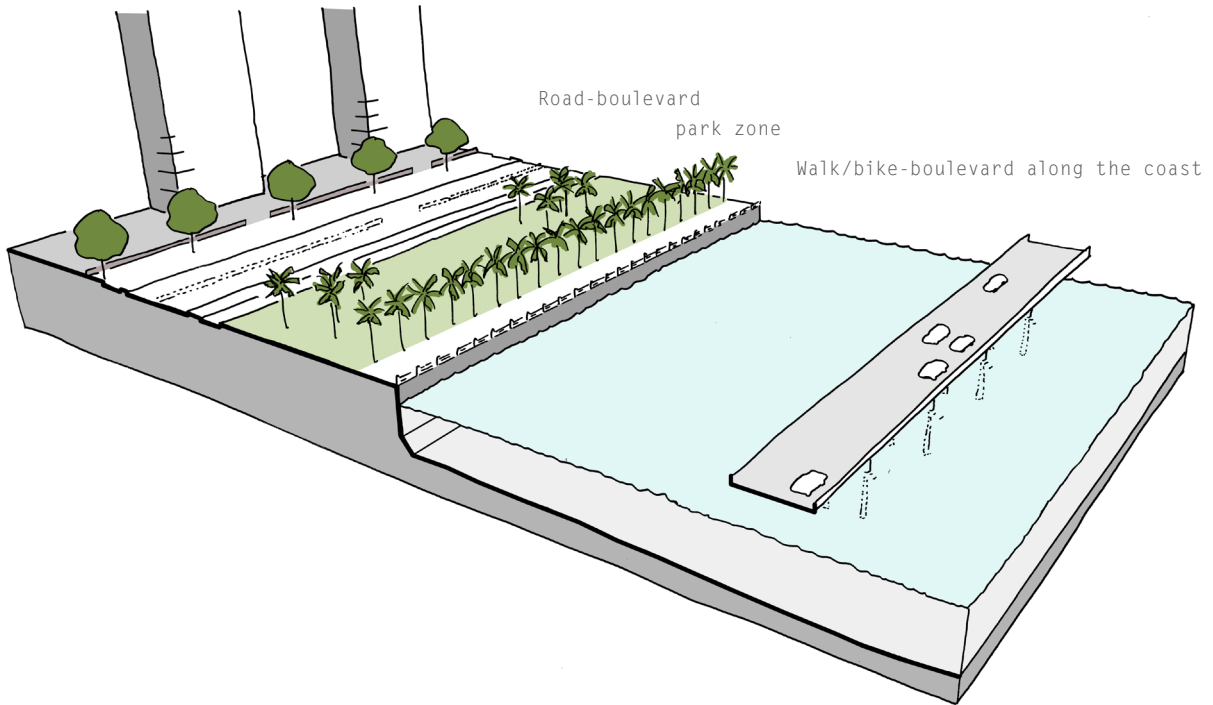


Off-shore construction close to the quay

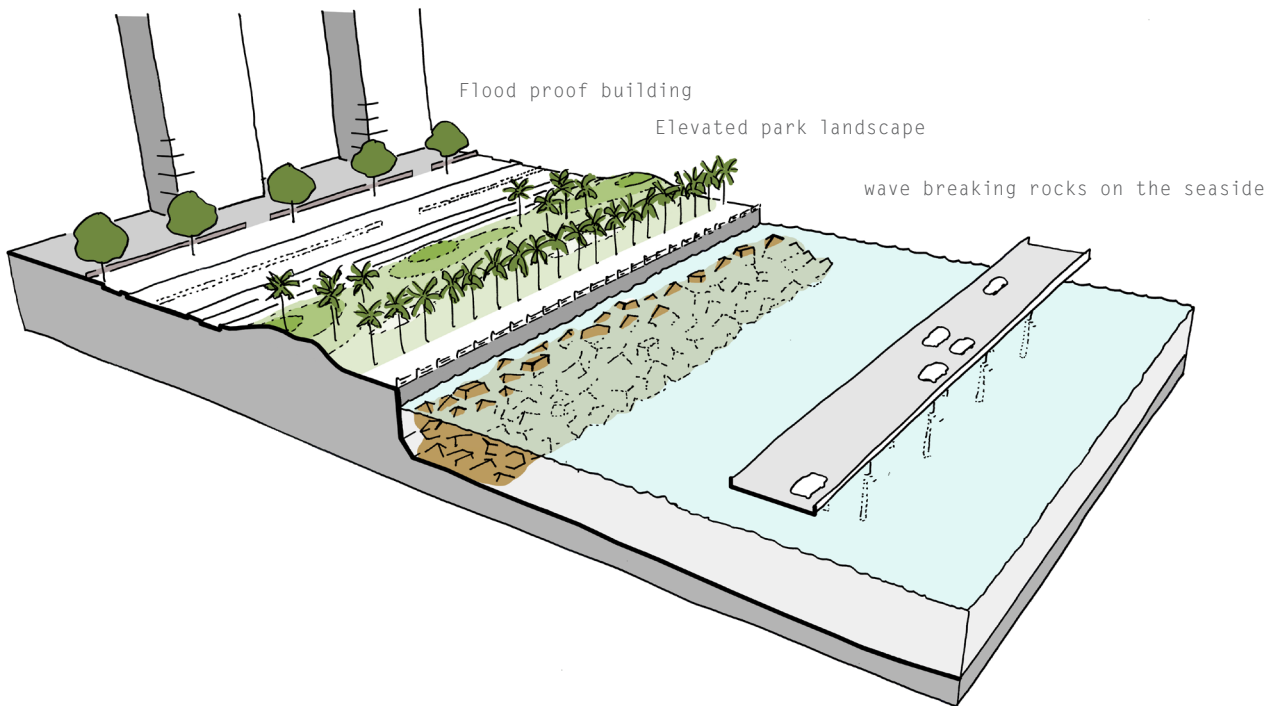


Green area along the coast with a view on the bay  
Elevation of critical infrastructure





Existing situation



set of propositions

# 4. Toolbox for Zhuhai

## 4.5 Toolbox for Jitimen river

A concrete levee protects the fish nurseries alongside the Jitimen River from flooding. On the horizon, the city of Zhuhai expands. Large infrastructure and residential expansions are visible. It is easy to imagine that this area will also become a neighborhood in the future.

Today, a concrete levee has been placed. A solution that takes up little space but offers little possibility for adaptation. Elevating the levee is the only way, but this makes the levee heavier for which the foundation is not suitable.

To make it resilient, the narrow concrete levee needs to be turned into a broader zone that can be used to provide flood safety. In addition to water safety, these solutions can offer several advantages for future use, ecology, minimal maintenance, etc.



Levee



Fish nurseries behind the levee



Levee



River outside the levee





Location of the levee

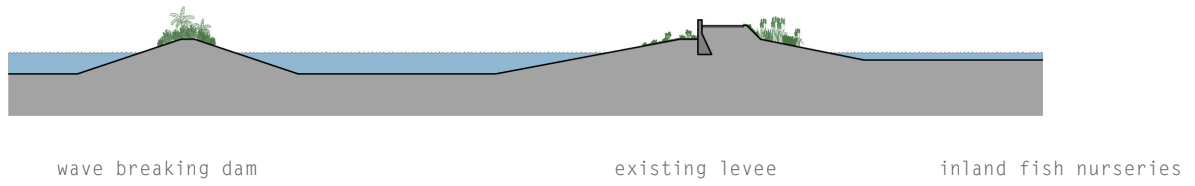
# 4. Toolbox for Zhuhai

## Toolbox for Jitimen river

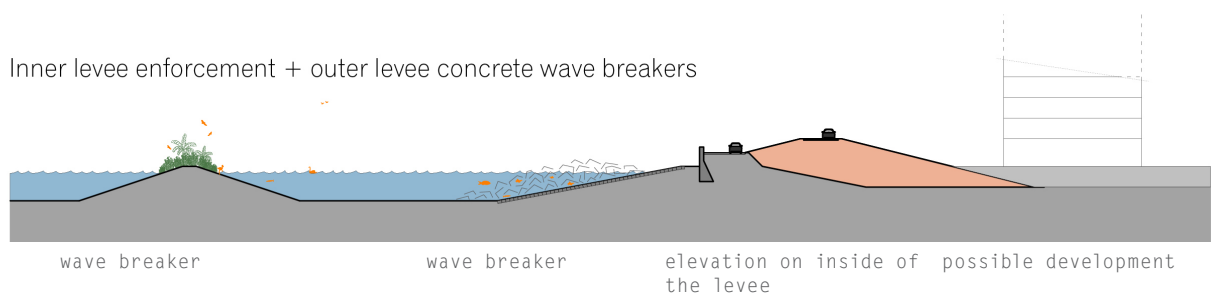
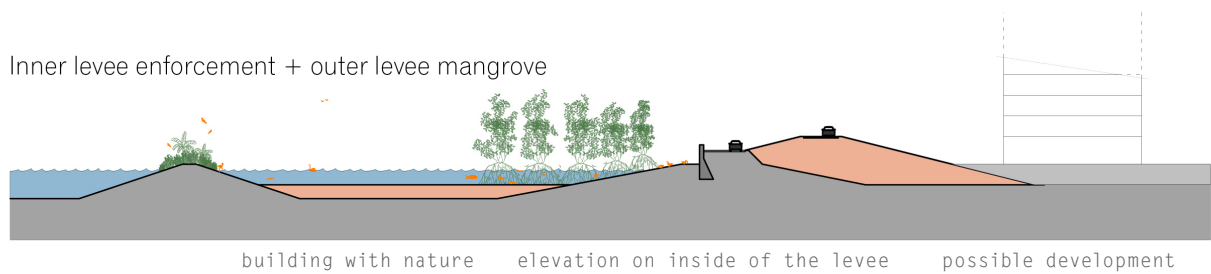
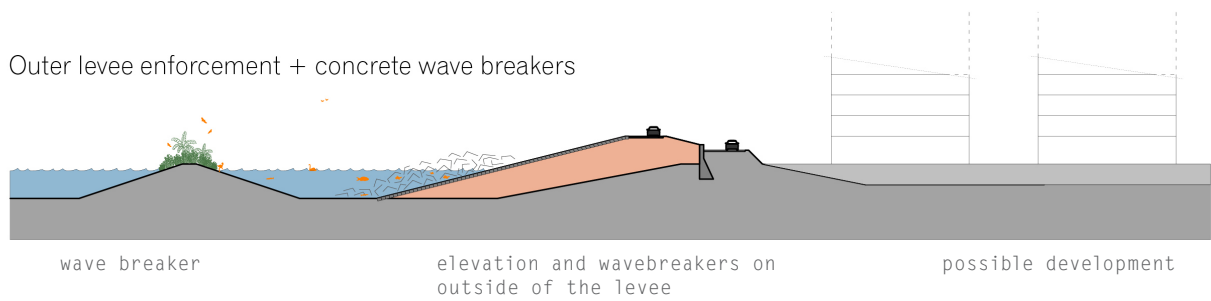
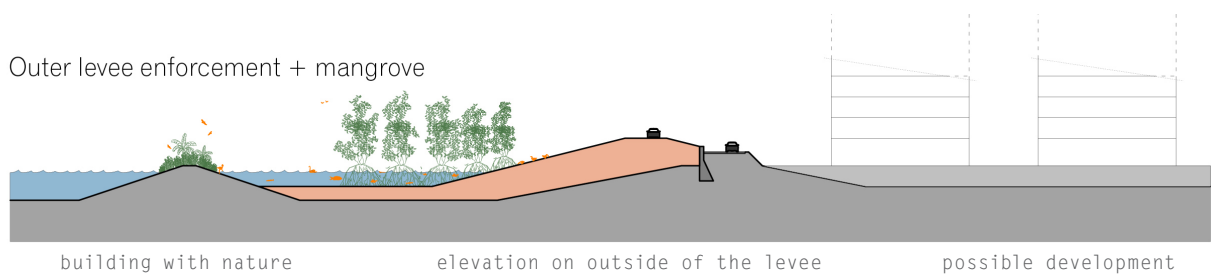
options inbound or outbound levee re-enforcement



### Current situation



### Levee enforcement

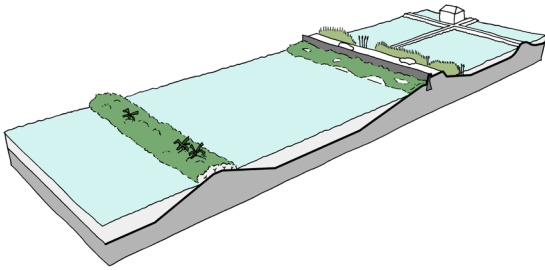


# 4. Toolbox for Zhuhai

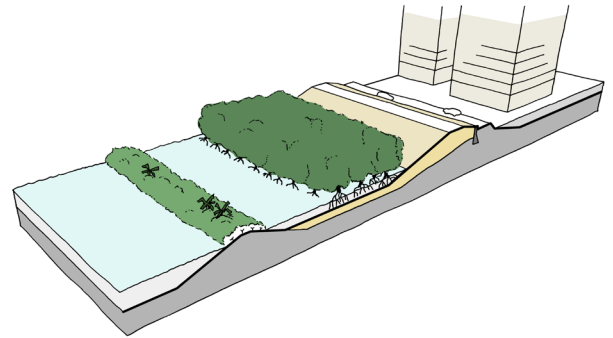
## *Jitimen river, inland levee re-enforcement*

### Toolbox for Jitimen river

options inbound or outbound levee re-enforcement

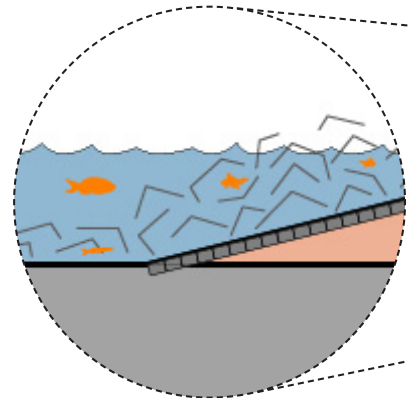


Existing situation

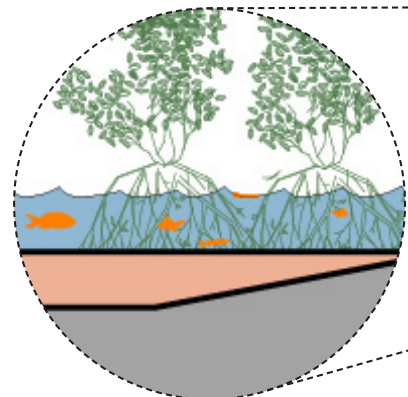


Building with nature protecting inland areas for flooding and providing green spaces for possible future development

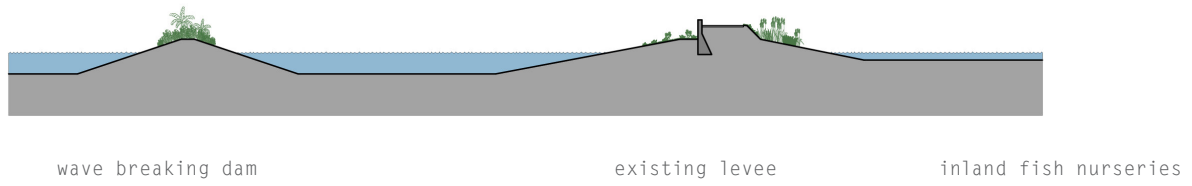
Biodiversity between wave breakers



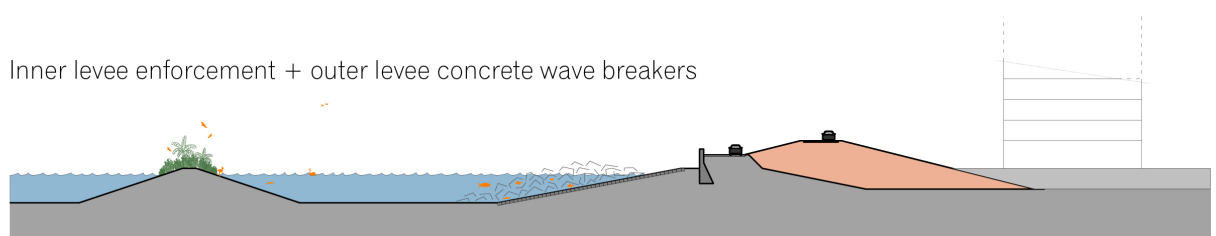
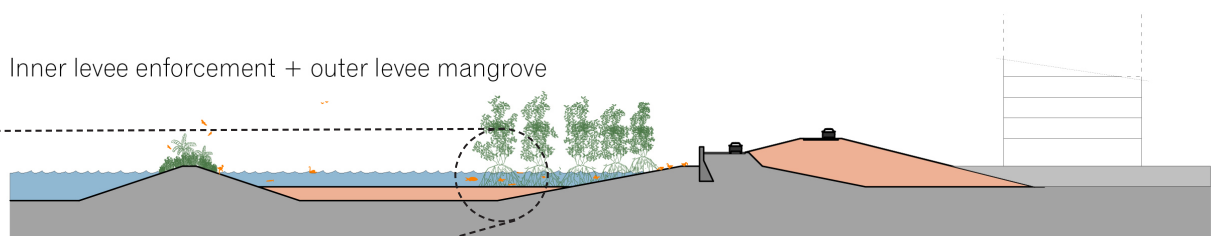
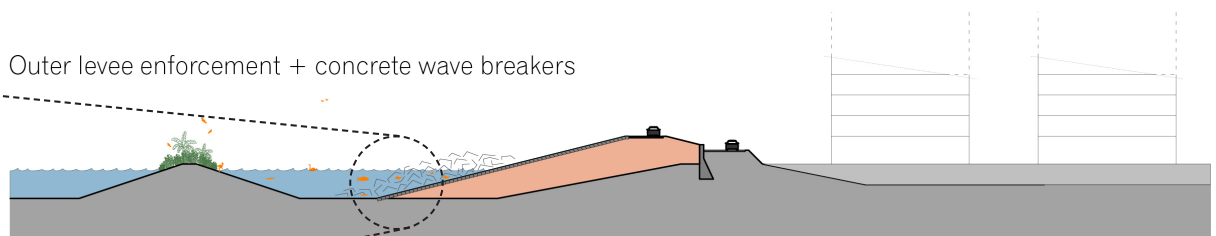
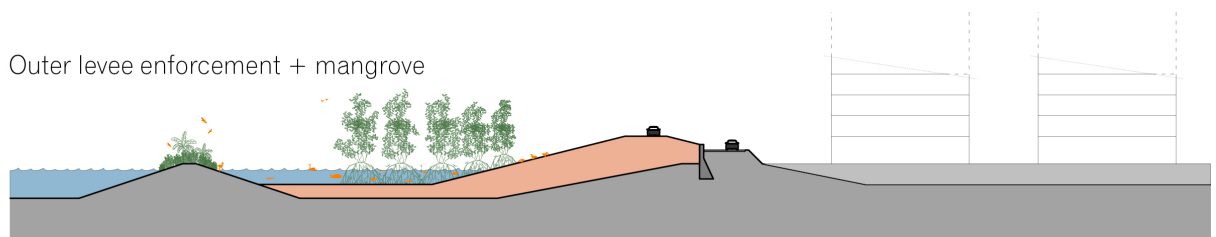
Biodiversity in mangrove forest



### Current situation



### Levee enforcement



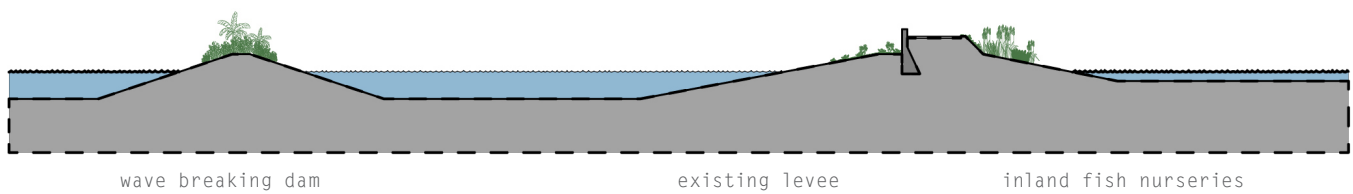
# 4. Toolbox for Zhuhai

## *Jitimen river, inland levee re-enforcement*

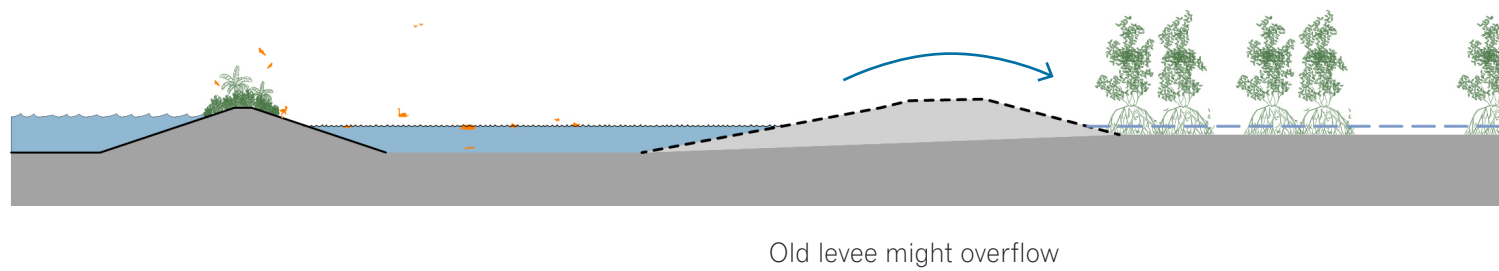
### Toolbox for Jitimen river

options inbound or outbound levee re-enforcement

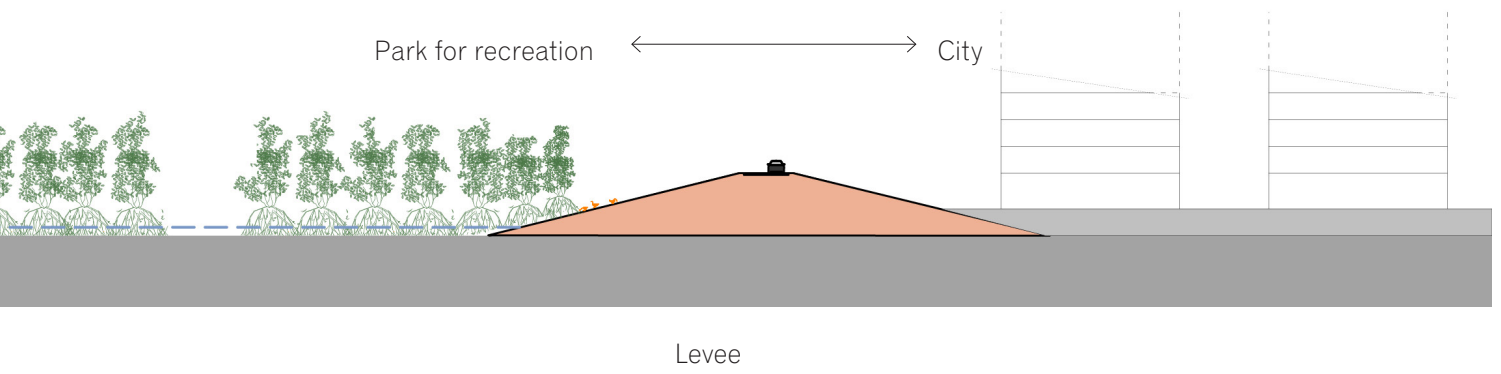
#### Current situation



#### Removal of current levee in order to create more space for water and biodiversity







## 5. Final recommendations

For a successful implementation on flood defence and climate resiliency the project team considered some recommendations to be essential. During the visits of Zhuhai and the process of consultancy and reporting the following recommendations were drawn.

### Establish a Regional Flood Defence Program on a Pearl River Delta scale

A robust flood defence policy requires cooperation on multiple levels of scale. A Flood Defence Program that suits Southern-China's characteristics should be addressing standing policies and processes on local scale. Roles and responsibilities of involved departments working on different administrative levels (national, provincial and municipality level) should be clarified and a strong coordination system should be in place. The Program will stimulate cooperation between local authorities, who will be able tackle specific challenges more efficiently, universities and research institutes, who can bring scientific knowledge and high-resolution modelling as well as other stakeholders (consultancy and developers). Broad stakeholder engagement will lead to a more transparent and efficient process, encouraging knowledge institutes and commercial companies to share research and new technologies more easily.

To secure people's lives, a national flood risk management system should be established to mitigate risks to and maximize the benefits of land utilization. Development should be limited in flood-prone areas and new dikes cannot be built without a flood risk analysis.

### Start an Awareness Program on flood safety measures

Low acceptance of flood defence projects with major impacts on the local surroundings and environment brings difficulties in realisation. Public awareness on the challenges and solutions on climate adaptation measures and flood defences can create broad support for complex projects. Public awareness and engagement should be increased through publicity, participation activities and public awareness programs.

### Start Pilot Projects to learn and adapt new flood defence principles

We suggest the introduction of a series of pilot projects for flood defence. In these pilot projects the broad scope of the presented toolbox-principles can be tested and evaluated in the local situation of Zhuhai. A steep learning curve can then be achieved in the dialogue with all stakeholders (local and regional scale).

## 6. Final note

This pilot project is the last to be supported by the EC-LINK project. This collaboration is just a start for further cooperation between the Netherlands and Zhuhai (and other Chinese cities). We hope that we can continue to exchange our knowledge and experience about sustainable urban development, learn from each other and work together for a sustainable world.

We greatly thank the following parties for their contribution:

- The EC-Link project team
- Zhuhai Municipal Bureau of Housing and Urban-Rural Development
- Zhuhai Municipal Bureau of Urban Planning & Land Resources
- Zhuhai Shishan community
- The China Academy of Urban Planning and Design

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**Europe-China Eco-Cities Link**  
中欧低碳生态城市合作项目



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서울

Huanghao River  
黄海水道

Pyeongyang  
平壤

Yalu Bay  
鸭绿湾

Wangja Bay  
望加錫灣

Yamato

Osaka Bay  
大阪灣

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