World Water Council
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Perspectives on water and climate change adaptation

Adaptation to climate change – Another challenge in the sustainable development of deltas

Deltares
Enabling Delta Life

This Perspective Document is part of a series of 16 papers on «Water and Climate Change Adaptation»

'Climate change and adaptation' is a central topic on the 5th World Water Forum. It is the lead theme for the political and thematic processes, the topic of a High Level Panel session, and a focus in several documents and sessions of the regional processes.

To provide background and depth to the political process, thematic sessions and the regions, and to ensure that viewpoints of a variety of stakeholders are shared, dozens of experts were invited on a voluntary basis to provide their perspective on critical issues relating to climate change and water in the form of a Perspective Document.

Led by a consortium comprising the Co-operative Programme on Water and Climate (CPWC), the International Water Association (IWA), IUCN and the World Water Council, the initiative resulted in this series comprising 16 perspectives on water, climate change and adaptation.

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

The consortium has performed an interim analysis of all Perspective Documents and has synthesized the initial results in a working paper – presenting an introduction to and summaries of the Perspective Documents and key messages resembling each of the 16 perspectives – which will be presented and discussed during the 5th World Water Forum in Istanbul. The discussions in Istanbul are expected to provide feedback and come up with sug• gestions for further development of the working paper as well as the Perspective Documents. It is expected that after the Forum all docu• ments will be revised and peer-reviewed before being published.

13 Adaptation to climate change – another challenge in the sustainable development of deltas

Mississippi Delta

Ganges Delta

The information contained in this perspective document has been derived to a large extent from a research on deltas in the framework of the Aquaterra 2009 Conference.

Herman van der Most, Deltares, P.O. Box 177, 2600 MA Delft, The Netherlands, herman.vdmost@deltares.nl.

Contributions of: **Marcel Marchand**, Deltares; **Tom Bucx**, Deltares; **Tjitte Nauta**, Deltares; **Martijn van Staveren**, Netherlands Water Partnership

Adaptation to climate change: another challenge in the sustainable development of deltas

Deltas are generally located at strategic locations close to seas and inland waterways. Deltas also provide some of the world's most fertile lands for food production. Attracted by these potentials, large numbers of people live in deltas. The rivers that flow through the deltas are an important source of fresh water and nutrients that create environmental conditions for a unique flora and fauna. Delta and estuarine ecosystems are therefore valuable and among the most productive ecosystems on earth.

1 Trends and issues in the development of deltas

1.1 Deltas: economic and environmental hot spots

The major river systems of the world all have a unique delta region, with their specific challenges and opportunities. But there are also common characteristics. Deltas are usually areas with major economic potential because of their strategic location close to seas and inland waterways. Deltas provide also some of the world's most fertile lands important for food production. That is why navigation and port development, oil production and refinery as well as agriculture and fisheries have always been the engines of economic development of deltas. Attracted by these potentials, large numbers of people live in deltas; a development which has led to the growth of coastal (mega-)cities.

Deltas have been formed by the sediments brought in by their respective river and shaped by the interplay of tides, waves and currents. At the seaside of a delta, these forces tend to erode and disperse the sediments. But as long as the net input of sediments exceeds the rate of erosion, the delta will grow. Such natural processes are crucial in the long-term evolution of a delta. A net deficit in sediment supply, for example, caused by construction of dams upstream, will lead to coastal erosion.

The rivers that flow through the deltas are an important source of fresh water and nutrients that are critical for sustaining life in the deltas. The mixing of salt and fresh water in the estuarine part of the deltas creates environmental conditions for a unique flora and fauna. Delta and estuarine ecosystems are therefore valuable and among the most productive ecosystems on earth.

But, being low-lying areas, deltas are also vulnerable to flooding and have to cope with stagnating drainage. That is why living in deltas has always required human intervention. Land reclamation, irrigation, soil drainage and embankments have made many deltas a safe place to live and work.

Box 1

Opportunities of deltas	Challenges in deltas
– strategic location close to seas and water ways	– areas vulnerable to flooding and drought
– high potential for port development and oil industry	– human intervention needed to safely live and work
– fertile soils and rich aquatic environment	– filter or sink for upstream pollution
– large potential for agriculture and fisheries	– areas with high pressure on available space
– valuable and most productive ecosystems	

1.2 Melting pot of drivers and trends

Population growth, economic development and climate change are the main drivers for change in deltas. These developments pose extensive demands on the available natural resources of deltas. In addition to these drivers there are a number of societal trends, which affect the organization and outcome of planning of delta development.

Box 2

Drivers for change	Trends in society
population growth: the global population still grows with some 2% per year, although there are distinct regional differences. The number of people to be served and to be protected against natural hazards will increase.	*decentralization*: brings delta issues closer to the stakeholders involved. Due to lack of national coordination there is, however, a genuine risk of uncontrolled and/or chaotic developments.
economic development: despite the current economic recession, economic growth may be expected over larger periods of time, resulting in larger demands to be met, higher values to protect, more energy to be generated and more goods to be transported.	*privatization*: public-private partnerships are becoming the modus operandi for new infrastructural projects and services. Increased efficiency of taxpayer's money is a key motive. The risk of privatization, however, is a focus in the short term as well as a neglect of the public interest.
climate change: although the extent of climate change may be subject to debate, there is general consensus that the rise in global temperature is inevitable, with its associated (local) impacts on sea level rise and the hydrological cycle (larger and more frequent droughts and floods).	*participation*: involvement of stakeholders and citizens is important to promote societal support of development projects as well as maintenance of infrastructure; planning may benefit from the tacit knowledge of stakeholders.
technological development: innovations may open opportunities to enhance the functionality of infrastructural solutions, to extend the life time of infrastructure and/or to develop more cost-effective designs.	*environmental concerns:* worldwide concern over a changing climate and environmental degradation has raised environmental awareness, influencing the valuation of impacts and the choice of measures.
	risk aversion: acceptance of risk is decreasing in our modern societies; hence considerable efforts are made to further reduce or control the risks of natural hazards.

Of these trends decentralization and privatization may be viewed as autonomous developments. The challenge is to utilize the advantages of both trends, while minimizing their undeniable drawbacks. This calls for a selective enhancement of governance structures, reflecting the regional scale, integrated nature and long-term perspective of delta development.

1.3 Overview of delta issues

The characteristics, which make deltas attractive areas to live and work, are under stress. Available space is under pressure, vulnerability to flooding is increasing and fresh water resources are threatened. Population growth, economic development and climate change will cause additional stress on deltas, unless appropriate measures are taken.

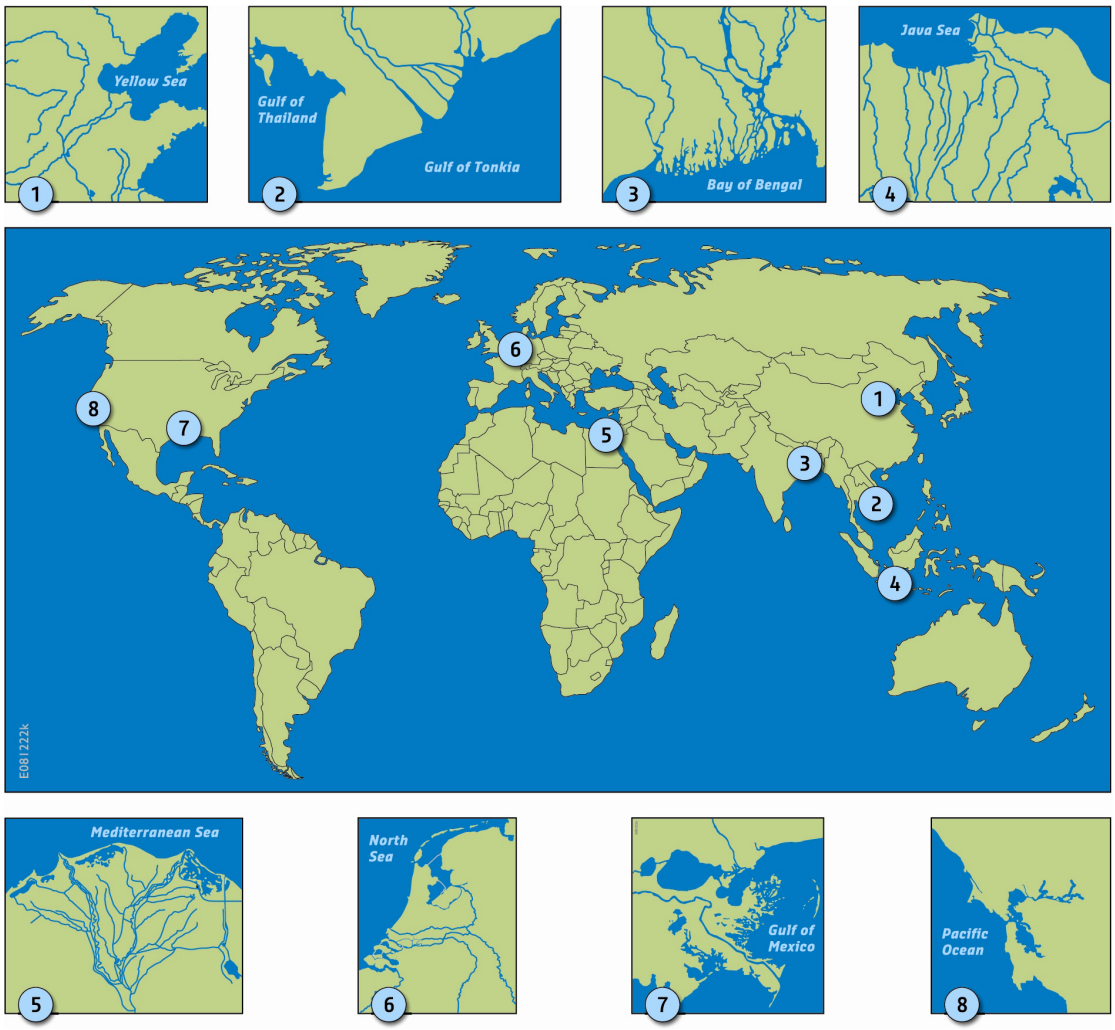


Figure 1: Eight selected deltas from the Aquaterra 2009 Conference.

Box 3 – **Main issues at stake in deltas**

Pressure on available space: being a focal point of economic development, population density is generally high and is rising. Coastal mega-cities have developed and their size and number are growing.

Vulnerability to flooding: being low-lying areas, deltas are vulnerable to flooding. Subsidence of soft soils adds to this vulnerability. Accumulation of people and wealth, as well as loss of resilience of soil and water systems, will further increase the vulnerability with respect to climate change.

Shortages of freshwater resources: many deltas in the world currently face water shortages. Climate change may result in more frequent and prolonged periods of low river discharges. This will have profound repercussions on the delta agriculture, as well as on delta and coastal ecosystems.

Ageing of infrastructure: many deltas have inadequate flood protection schemes or schemes that require major upgrading. Other deltas have irrigation and drainage systems which require an upgrade or major revision to improve their effectiveness.

Erosion of coastal areas: many deltas face a sediment shortage. This sediment shortage is often caused by regulation works in the upstream river. The sediment shortage causes coastal erosion problems. Sea level rise will aggravate these erosion problems.

Loss of environmental quality: ecosystem functioning and biodiversity in deltas are under very high pressure worldwide. Main causes are a high population density and concentration of agricultural, industrial, harbor and mining activities. Deltas are also the receptor of pollutants from upstream.

1.4 Issues of selected deltas from the Aquaterra 2009 Conference

In preparation of the Aquaterra 2009 Conference a quick assessment has been made on the nature of delta issues in eight selected deltas. The table displays to what extent issues play a role. The classification distinguishes four types of problems. Problems are judged minor if they are either unimportant, small in magnitude or well controlled (•). A minor problem can become bigger in the future (e.g. due to climate change or delta developments) in which case it is given two bullets (••). An issue is classified as a current big problem if the issue is requiring significant management attention and is not (yet) controlled (•••). If the problem is likely to increase in the near future it is given four bullets (••••).

The outcome of this assessment is summarized here in a comprehensive table. The main report on trends and responses provides some short explanations for the assessments, whereas the delta descriptions provide further background on the issues at stake in the eight deltas. The assessment is certainly subjective and reflect our understanding of the issues at stake in the eight deltas. Within the short time span of the research we may have overlooked certain aspects, so individual assessments may need revision. The main purpose of the overview is, however, to show that there is a large variation between the eight deltas. For example vulnerability to flooding is a major issue in most deltas but not in all. The table also shows that some deltas have to deal with a range of major issues, whereas in other deltas most issues are minor or at least under control. A few revisions of individual assessments will not alter this overall picture.

Box 4 Issues Delta	Pressure on space	Flood vulnerability	Freshwater shortage	Ageing or inadequate infrastructure	Coastal erosion	Loss of environmental quality and biodiversity
Yellow River Delta (China)	••	•	••	•	•••	•••
Mekong River Delta (Vietnam)	••	••••	••••	••	•	•••
Ganges–Brahmaputra Delta (Bangladesh)	••••	••••	••	••	••••	••••
Ciliwung River Delta (Indonesia)	••••	••••	••	••	•	••••
Nile River Delta (Egypt)	••••	•	••••	••••	••	••
Rhine River Delta (The Netherlands)	•••	••	••	•••	••	•
Mississippi River Delta (USA)	•	••••	•	••••	••••	••••
California Bay (USA)	••	••••	••••	•••	•	•••

Legend:

- • relatively minor problem, now and in the near future
- •• currently a minor problem, but is likely to increase in the near future
- ••• currently already a big problem, future trend uncertain
- •••• currently already a big problem, likely to increase in the near future

1.5 Impact of climate change on delta issues

Climate change has an impact on most of the delta issues presented in Box 3. The vulnerability to flooding may increase substantially due to sea level rise. Shortages of freshwater resources are another important impact. The frequency and extent of such shortages will be influenced by prolonged periods of low river discharges, as well as by a reduction in local precipitation. Climate change may also impact the lifetime of infrastructure, because the physical conditions may become more severe compared to the conditions for which the infrastructure has been designed. Coastal erosion problems may aggravate because of sea level rise. Climate change may also result in a reduction of freshwater supply to the delta, which in its turn may jeopardize the ecological integrity of delta ecosystems.

2 Planning of delta development

2.1 Dealing with drivers and trends

The drivers and trends pose tremendous challenges to delta management. Existing management approaches and tools are not always adequate as they tend to tackle these challenges in a piecemeal and sector wise way. For example, in many countries a full-fledged Environmental Impact Assessment legislation is operational. Although this is a great improvement over past practices that neglected the negative consequences of development projects, it mostly does not account for multiple and cumulative impacts. Also planning regulations and limitations do not always serve an optimal spatial development. It has been long standing-knowledge that nature conservation by means of protective areas or reserves has significant limitations. Endangered species get trapped in those isolated havens as their habitat becomes unsuited due to climate change.

These are but some examples of the difficulties delta management is confronted with. As a way out, a more holistic and integrated view on delta management is taking shape. We see this, for instance, in integrated water management, coastal zone management and at the scale of entire river basins. But there is more: ideas to reconcile human development with nature are emerging in various fields. ‘Building with Nature’ is practiced already in the form of beach nourishments as opposed to hard structures to control erosion. Multifunctional use of infrastructure is being implemented in densely populated deltas to save space and money. Restoring the natural purification capacity of wetlands and estuaries are being considered in highly modified deltas, such as in the Netherlands.

To promote sustainable development of deltas, a clear vision has to be developed on how to respond to the various drivers of change as well as on how to play along with the various trends in society. A strategy for sustainable development of deltas should comprise a sensible combination of different kind of responses. This should include measures for management and restoration of natural systems, for development and adaptation of land and water use and for extension and revitalization of infrastructure. Furthermore enhancement of the governance structure is required to enable implementation of these responses. The perspectives of these responses will be discussed in the next sections of this document.

2.2 Conceptual view on planning of delta development

The sustainable development of a delta may be analyzed and managed using the so-called ‘layer model’. The layer model divides the space in three physical planning layers, each with their own dynamics. These layers are the base layer (water and soil), the network layer (infrastructure) and the occupation layer (physical pattern arising from human activities: living, working, recreating; in short: land and water use). The essence of the layer model is the difference in dynamics and vulnerability between the layers, which results in a logical order in planning the various layers. The layers enable and/or constrain activities in another layer.

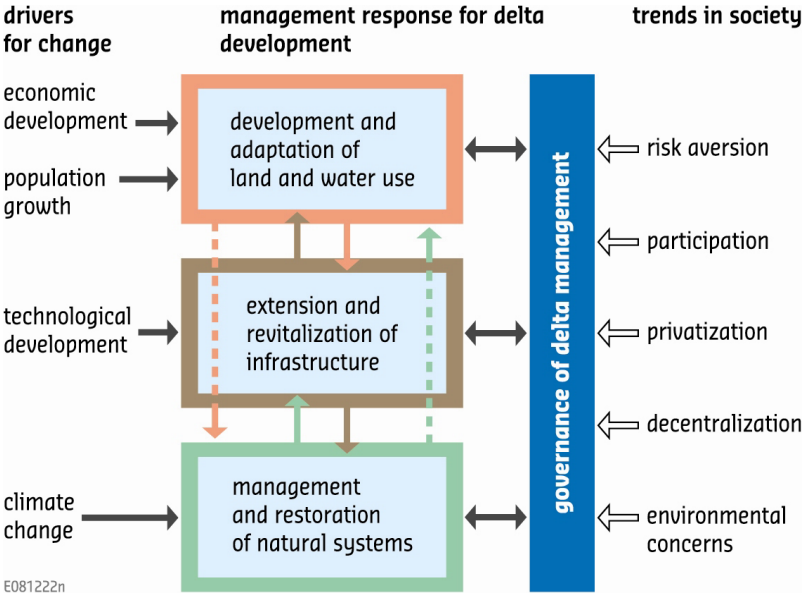


Figure 2: Linking responses to drivers and trends.

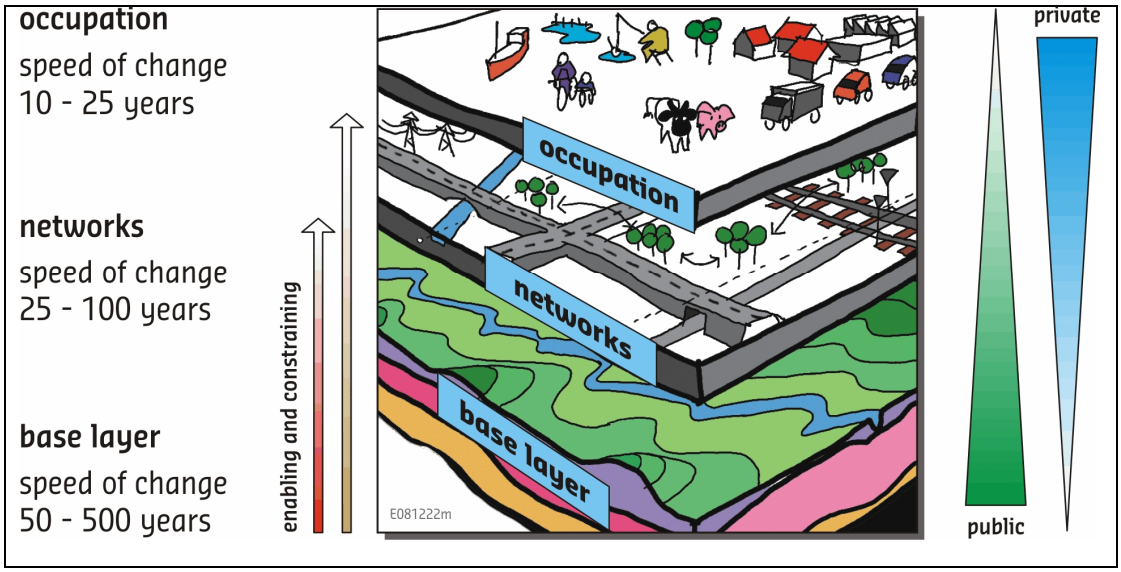


Figure 3: Layer model for planning of delta development.

The layer model may be instrumental in, for example, the design of strategies for adaptation to climate change. The key to adaptation to climate change (climate proofing) lies in the base layer. If the structure of the base layer is climate proof, then the other layers follow suit. This is not a matter of hierarchy or dominance but of logical order- the base layer first. The climate proofing of the base layer is the sole responsibility of government. The way to act is to make maximum use of the large adaptive capacities of natural systems. Moving to the occupation layer the role and influence of government becomes more restricted and the influences of private parties and citizen's interests become more dominant.

2.3 Perspectives on development of deltas

Basically there are two different ways to respond to the different drivers and trends. The first perspective is very much driven by the (liberal) economic perspective: the role of the (central) government is reduced through privatization and decentralization. Also there is less government influence in spatial planning, etc. The balance between central and de-

central is a political issue. It is a response to a growing complexity in society and therefore a trend. The word privatization indicates that there is an existing public service that can be given to the market. There are also many new services to be developed which require a vision on private sector development and involvement. The challenge is to find the right balance between governmental supervision and control, and the dynamics, innovation of free market forces. The conflicts that could arise out of the market-driven and less top-down controlled focus are generally solved in a technocratic way, i.e. by further development of infrastructure. This perspective reflects a high belief in our capabilities to engineer the world to our needs. The long-term sustainability, however, is not guaranteed. Changing environmental conditions will require a regular upgrading of the infrastructure, as infrastructure does not adapt naturally.

The second, environmental perspective, is driven by global concerns on climate change and environmental degradation. It reflects a growing awareness that nature poses limits to development. These limits may be stretched to some extent through the development of infrastructure but at increasing costs. In this perspective land and water use should instead be adapted to changing environmental conditions through spatial planning regulation and adaptive designs. Natural processes should be utilized as much as possible to adapt to changing environmental conditions. The environmental perspective aims to make better use of the inherent adaptive capacities of nature.

The first perspective is visible in most deltas of the world. The second perspective is, as yet, less visible, but is gaining momentum. The two perspectives are basically conflicting. The main challenge therefore is to combine elements of both perspectives into a strategy which is both economically viable and ecologically sound. It requires among others harmonizing and balancing on the government axis – market, and on the central axis – de-central.

2.4 Development of adaptation strategies

Making deltas climate proof requires new adaptation strategies which are timely, technically and environmentally sound, economically feasible and socially acceptable. However, both climate change and socio-economic developments come with large uncertainties. In order to develop adaptation strategies for climate-proof deltas, fundamental questions need to be answered, such as:

- What are the requirements which the key economic sectors (e.g. agriculture, transport, energy, tourism, industry) and nature put on water management and spatial planning in deltas?
- Under what circumstances do current strategies for water management and spatial planning fail to meet those requirements (when, where, how often)?
- What are the adaptation options that will allow us to keep on living and working in the deltas?
- How much time is available to implement these adaptation options for water management and spatial planning?

To answer such questions an integrated method is required to assess the vulnerability of deltas and to determine adaptation paths for the different sectors in deltas. One of the key elements in such method is the so-called adaptation tipping point. An adaptation tipping point is a level where natural (physical) boundary conditions exceed technical, economic, spatial or societal acceptable limits. Figure 4 presents an example on the suitability of a delta for human settlement as a function of sea level rise. The straight line represents conditions for the present adaptation capacity, the dotted line represent conditions under new adaptation strategies. The adaptation tipping points are indicated as an (*). The risk of coastal flooding might at first be reduced to an acceptable level by intensified shoreline management. If that strategy reaches its limits it may be followed by the construction of new super levees. An adaptation tipping point identifies the point where a policy on water management or spatial planning needs to be revised and where a new strategy needs to be implemented.

The adaptation tipping points method (Deltares, 2008) takes the requirements of key sectors of water management and spatial planning as a starting point to identify the need for adaptation to climate change. The degree of climate change to which each key sector can cope is determined. Climate change scenarios are then used to determine in which time period those adaptation tipping points may be reached. This provides insight into the vulnerability to climate change of deltas. Combining the adaptation tipping points with local scenarios will identify the vulner-

ability of a sector and the possible need for new adaptation strategies.

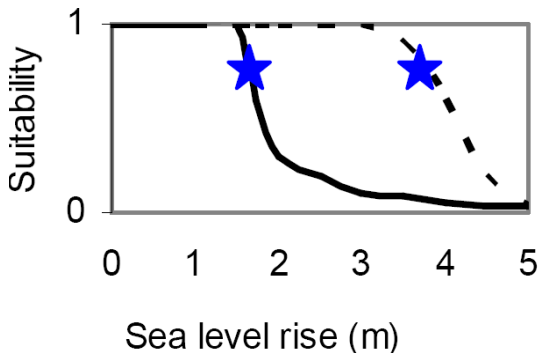


Figure 4: Examples of the relationship between natural boundary conditions and the suitability of a delta.

The timing of adaptation tipping points is crucial knowledge for decision-makers. Knowing how long it will take before adaptation tipping points are exceeded makes the timeframe for decision-making explicit. The timeframe for a certain adaptive measure can be estimated by using climate change scenarios and socio-economic scenarios. Some adaptive measures will have to be implemented soon, and others in the next 20 or 50 years or even later.

The method may also help to develop a sequence of adaptations strategies, so-called 'adaptation paths' (Figure 5). Replacing Strategy 1 by Strategy 2 will happen at a certain level of climate change. It could even lead to a higher efficiency of use of the delta area. When the efficiency of the final strategy becomes too low, retreat from the deltas becomes unavoidable.

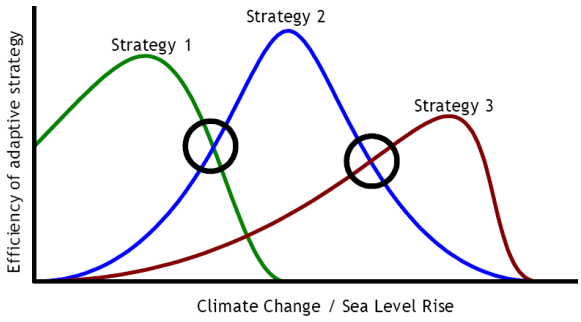


Figure 5: Adaptation paths to climate change for water management in delta areas.

The adaptation tipping point method has been successfully applied to the water resources system of the Dutch Delta to support the analysis and recommendations of the Delta Committee (see Box 5).

Box 5 – **Adaptation tipping points analysis for Delta Committee**

Research findings adopted in the report of the Delta Committee include:

- Fresh water supply will be severely hindered through salt water intrusion, but it will not be an issue before 2040;
- Speed of sea level rise (the higher scenarios) will come close or exceed the natural adaptive capacity of the Wadden Sea;
- The Maeslant storm surge barrier in Rotterdam, has been designed for sea level rise up to 50 cm, hence this will not be an issue before 2060;
- Current strategy for nature conservation will not be sustainable under climate change;
- Salt water upward seepage through the ground water is a minor effect;
- Coastal flood defense maintenance through sand nourishment will not be an issue, provided that sand can be taken from the North Sea bed;
- In general it was concluded there are no limitations to technical adaptation measures, although these measures become increasingly expensive and space consuming.

3 Perspectives of restoration of natural systems

Deltas are relatively young landforms shaped by the interplay of coastal and riverine processes. These natural processes are crucial in the long-term evolution of a delta. The delta estuaries and its marine environs have the highest biological production of all natural areas in the world. Estuaries have also the highest economic value of all ecosystems. The most important direct drivers of change in ecosystems worldwide – and probably also for delta ecosystems – are habitat change, overexploitation, invasive alien species, pollution and climate change (in particular sea level rise).

Delta ecosystems can be relatively easily restored, because the delta environment is highly dynamic. Delta nature has a remarkable adaptive and resilient capacity. In contrast to, for instance, tropical rainfor-

ests which require centuries to reach a climax succession stage, delta ecosystems, such as salt marshes, mangroves and dunes develop quickly into rich habitats once the environmental conditions are favorable. All over the world we see restoration ideas turning into reality. Of course not every initiative is an immediate success. There is much trial and error. But the most important thing is that people see the need to protect their environment and to work with nature instead of against it.

3.1 Restoration of resilience

Deltas are often confronted with coastal erosion, salt intrusion, subsidence, extreme high and low river discharges and changes in precipitation and evaporation. All these processes are affected by climate change, which make deltas vulnerable to climate change. In many deltas the developments over the past few decades have modified soil and water systems. The area of surface water has become less, and so has the water storage capacity. Changes of land use, including the creation of impervious surfaces, have accelerated the rainfall-runoff process, making these areas more vulnerable to flooding. The resilience of natural systems (the capacity of systems to adapt to other conditions through natural processes) has generally deteriorated.

Adaptation to these changing conditions is a major challenge. Adaptation strategies should focus on restoration of resilience. Such strategies should include measures to enhance infiltration, retention and/or storage capacities of water systems. Adaptation in densely populated deltas may also include multifunctional use of areas, e.g. giving a water storage function to nature areas. Reducing the vulnerability of land use through adaptive designs is another important pillar of adaptation strategies, for example through urban flood management.

3.2 Wetlands restoration for natural coastal protection

There is ample evidence that coastal protection can greatly benefit from a resilience-based approach. Many of the world's coastlines are highly dynamic by nature through the forces of winds, waves and currents. Hard engineering structures have more often than not led to increased erosion, either on the location itself, or at nearby, unprotected beaches. Instead, coastal practitioners are increasingly applying soft engineering measures, such as beach and foreshore sand nourishments.

Besides - and in addition to - these sand nourishments, ecological engineering is being practiced. Based on the notion that mangroves can provide effective storm protection, there is increased attention to restore these coastal forests. Great potential exist to reverse the loss of mangrove forests worldwide through the application of basic principles of ecological restoration using ecological engineering approaches. Mangrove restoration can be successful, provided that the hydrological requirements are taken into account, which means that the best results are often gained at locations where mangroves previously existed.

3.3 Building with nature

Environmental considerations play a major role in the sustainable development of deltas. Concerns on environmental degradation have been institutionalized into environmental regulation. Almost no infrastructural development takes place without a proper environmental impact assessment. It is, however, not always easy to specify the environmental requirements to be met. These requirements are often subject to debate, and are sometimes hard, if not impossible to meet. That is why a different approach is being advocated: not to try to minimize the negative environmental impacts, but instead to make better use of the forces, interactions and materials present in nature. This approach reflects a shift in paradigm from building against nature to 'building with nature'.

The emphasis of the concept of building with nature is on sustainable development in densely populated coastal and delta areas. In implementing the method a new flexible dynamic equilibrium coastline is created using sand from the sea. The emphasis is on flexible soft structures in harmony with the sea, such as dunes and beaches. Building with nature has shown to be an environmentally friendly and economically advantageous concept. It offers inherent flexibility and adaptability, important for adaptation to climate change. The concept is applicable in many settings and supports long-term

sustainable solutions for the restoration of coastlines and habitats and in new approaches for land reclamation.

4 Perspectives of adaptation of land and water use

One of the trends in the development of deltas is an increasing awareness that occupation should be adapted to changing environmental conditions. Due to climate change, but also population growth and economic development, the demands of land and water use will change. In particular the threat of climate change is an important trigger for the adaptation of land and water use. This threat may be countered to some extent by regulation of spatial planning: promoting (new) activities in low-risk areas to minimize the (increase in) vulnerability to climate change. If spatial planning offers little solace, solutions may be found in restructuring an area, for example, in the reconstruction of urban areas so that more space may be created for storage of excess rainfall. Urban flood management is another example. Finally at the lowest scale, vulnerability may be reduced through adaptive designs and construction methods. This may include amphibious housing, shifts to more salt-resistant cropping patterns, etc. This section describes a few examples of adaptation options.

4.1 Spatial planning and zoning

Historically environmental conditions played a major role in the spatial 'planning' of land and water use. The available natural resources as well as the transportation potential were major reasons to occupy deltas. Infrastructure development was necessary to take full advantage of the benefits deltas had to offer.

Due to the debate on climate change as well as the occurrence of some major floods in the past few years there is a trend to take better account of the limitations and risks posed by the natural system. For example, there have been scenario studies in The Netherlands on spatial development. One of these scenarios included diverting new investments and urban development to areas with less or no flood risk. The new Delta Committee in its report, however, concluded that there is insufficient ground for such strategy. Even under severe unfavorable climate change scenarios, The Netherlands will be able to keep the water out with its flood control system, albeit with some additional measures.

The awareness that deltas are potentially risky areas is nevertheless growing, and more so in view of climate change. But in practice there are as yet few examples of formal risk based spatial planning. The UK, however, has regulations for spatial development and flood risks, the Planning Policy Statement 25 (PPS25) on Development and Flood Risks.

4.2 Urban (re)development and urban flood management

Economic development and population growth drive expansion of built up areas. The augmenting rate of built up areas in cities leave less space available for water storage functions. This is an unfortunate situation in deltas as it increases the vulnerability for floods and droughts. Urbanization leads to an increased tension between land and water development.

Over the last decades there is a growing number of floods in urban areas. Climate change and rapid urbanization will exacerbate this trend. Flooding incidents in urbanized catchment areas can lead to great public concern and anxiety, and the economic impacts are often severe. Besides structural measures aiming at a reduction of the probability of flooding, new integrated approaches are being developed and implemented. Urban flood management aims to incorporate flood risk into urban (re)development and tries to increase robustness as well as the adaptive capacity towards future flood impacts.

4.3 Adaptation to salinity problems

Salt accumulation in delta soils, resulting from intense irrigation and/or seepage, reduces agricultural productivity. Hence alternative practices are introduced to adapt to changing environmental conditions:

- desalting of agricultural soils;
- cropping of salt tolerant species;
- mixed farming practices.

Brackish agriculture using salt-tolerant crops is considered a promising strategy for over 100,000 ha of

arable land below sea level in the Netherlands. Due to increasing seepage because of sea level rise, the soil in these areas will become increasingly salty. The return on normal crops will consequently falling sharply. Cultivation systems and market opportunities for salt-tolerant crops therefore provide new perspectives for agriculture in these regions.

In the Mekong Delta of Vietnam some 800,000 ha (20% of the total area) is affected by saline water with predominant freshwater in the rainy season and brackish water in the dry season. As saline water intrusion in the dry season is a major constraint to rice farming, many farmers develop an alternating rice-shrimp farming system. This system produces shrimp in the dry season and rice in the wet season on the same plot. In this farming practice saline water is used to flood the rice fields in the dry season to raise shrimp. At the beginning of the wet season, farmers flush salinity out of their fields using rain and fresh river water to plant rice. The integrated farming systems increase farmers' income and improve the living standards of the local community.

5 Perspectives of infrastructure development

5.1 Towards more robust infrastructure

There is a trend in how societies deal with risks, including those from natural hazards. Many societies show a growing aversion of risk. Although zero risk is impossible many countries are adopting strategies which aim at a (further) reduction in the probability of failure as well as the impacts of failure. For example, the Delta Committee in The Netherlands recently recommended to raise the level of safety with a factor 10. The increase in safely level responds to the increase in the number of people and assets to be protected.

The trend of risk aversion, together with the expected impacts of climate change, has triggered a demand for more robust flood defence works. The super levees in Japan are a good example of such robust works.

Similar to the concept of super levees in Japan, Dutch engineers and landscape architects have developed the concept of climate dikes or Delta dikes. These Delta dikes, thanks to their height, width or structural reinforcements should be so strong that uncontrolled flooding is practically excluded. The Delta Committee has recommended adopting this concept particularly in those dike ring areas which are most vulnerable to flooding.

In addition to the trend of more robust infrastructure there is a need for more flexible systems. These are systems that are able to cope with uncertainties and will hence have the capability to adapt to new, different, or changing requirements. To develop these flexible systems, new design approaches and techniques are needed that recognize the value of flexibility and promote a more modular approach to water management.

5.2 Securing future water supplies

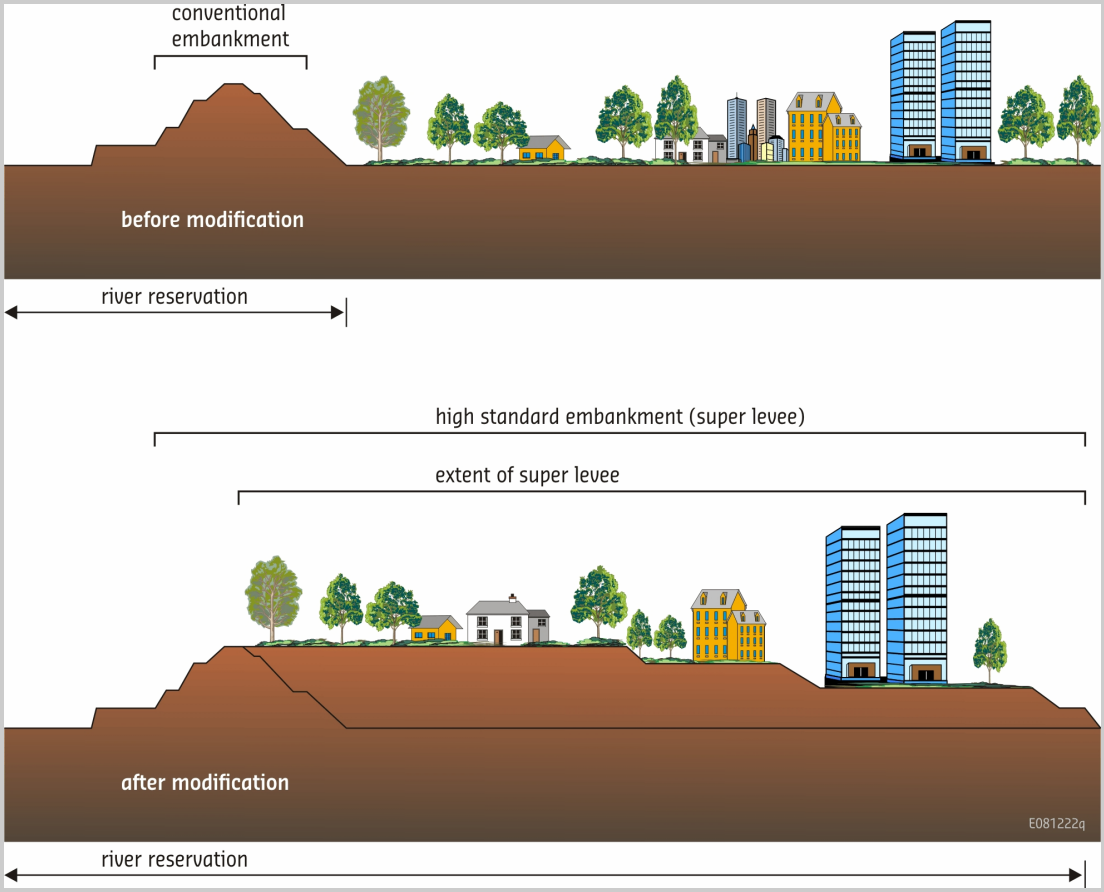
Due to climate change, prolonged and more frequent periods of drought are expected. At the same time water demands in deltas are increasing because of population growth and economic development. As a consequence water shortages will grow in magnitude and frequency, unless land and water use will be adapted or future water supplies will be improved either by storage or transfer.

In many countries shortage of fresh water is viewed as one of the most serious challenges in water resources management. Even in a country such as the Netherlands, with generally an abundance of water, droughts occasionally occur. Due to climate change, water shortages are expected to become more likely and counter measures are being considered. In fact, the Delta committee has proposed to raise the target water level of Lake IJssel by some 1.5 m to increase the amount of water being stored. The water from this lake constitutes a source of water supply to other parts of the country in periods of drought.

The expected increase in water shortages is also a major trigger for adaptation to climate change. Although in some countries such as Spain, the drought problems are so acute that emergency measures are taken.

Box 6 – **Super levees: Japan's response to increasing flood risks**

To respond to increasing flood risks with its devastating consequences to society, Japan had developed the concept of super levees. A super levee is a river embankment with a broad width which can withstand overflow. It prevents uncontrolled flooding due to a dike break. The slope of the embankment is made very gentle. In the unlikely event that the river rises above the embankment, the water would spill 'gently' down the slope. The embankment is protected from destruction and serious damage to assets along the river is minimized. The super levee differs from the conventional embankment, which is basically a wall separating the hinterland from the river.



The adaptation of conventional dikes to super levees offers a number of benefits. A super levee is better resistant to overflow, seepage and earthquakes. In addition it provides usable land and space for urban developments and it restores access to the riverfront. The concept of super levees is also a good example of multifunctional use of infrastructure.

5.3 New impulses for hydro energy

Economic development, unless serious energy saving programmes are implemented, may imply a growth in energy consumption. In line with mitigation policies for climate change there is a growing interest in the potential of deltas for renewable energy. Specifically in deltas there are a number of ways in which water may serve as a source of sustainable energy, waiting to be tapped. These include energy from tides, from waves and from salinity gradients.

The opportunities of water for energy generation have been explored in an innovation programme in The Netherlands. The study looked into the potential of the various sources, and the perspectives for actual generation from both a technical and societal point of view. The perspectives of energy generation from

tides and waves in the Netherlands were found to be rather limited. Most potential is in the generation of energy from fresh-salt gradients using Pressure Retarded Osmosis (PRO) and/or Reversed Electrodialysis (RED). The Closure dam which separates the fresh water of Lake IJssel from the Wadden Sea might be a suitable location for the application of this technology. Its application may become part of the required rehabilitation of the Closure dam and would comprise a good example of multifunctional use of infrastructure as well.

Box 7 – **Water shortages and adaptation to climate change (example from Spain)**

The drought problem in Spain is treated rather separately from the adaptation to climate change, despite the obvious and recognized link between the two. In general, drought is regarded as an emergency issue and many ad-hoc actions are taken. This happens often on a short timescale, which does not necessarily fit with the long-term adaptation to climate change. Many activities aim at solving particular bottlenecks caused by drought, especially in the irrigated agriculture. Examples of such measures are the implementation of interbasin transfers, a much disputed issue in Spain, as well as the continuous inauguration of desalination plants, especially close to the major coastal cities such as Barcelona. These kind of drought-driven activities are sometimes included in plans for adaptation to climate change, but tend to be implemented independent as a kind of 'no-regrets' measure.

5.4 Rehabilitation of infrastructure

Due to climate change the physical conditions for which the infrastructure has been designed will become more severe, such as larger droughts to overcome, higher water levels to counter and larger loads to withstand. Climate change, without adaptation or counter measures, will result in damage or a loss of functionality of the existing infrastructure. The adequacy of the infrastructure may be further challenged by physical / mechanical ageing of the infrastructure. Also inadequate maintenance may play a role. Some infrastructure which has already been present for decades or centuries is in (urgent) need of replacement or rehabilitation. Such rehabilitation will require large investments in the near future. Hence it is important to anticipate such expenditure.

6 Perspectives of enhancing delta governance

In the past few decades the development and management of deltas has become increasingly complex and often an issue of societal debate. A number of trends have added to this complexity, including decentralization of government and larger involvement of the private sector. Also interest groups and citizens have a stronger voice in development. Sustainable development and management of deltas has to deal with this increased complexity; it calls for a strengthening of the governance structure. Good governance is in fact a permanent search for a proper balance between public and private interest, between efficiency and equity, between different regions and sectors, between economic development and environmental stewardship.

Box 8 – **Foundation of a Delta Council in the Southwestern Delta of the Netherlands**

Some years ago the provincial managing authorities have drafted a vision for the future. This vision deals with both the ecological side effects of the Delta Works and the expected impacts of climate change. Restoration of estuarine dynamics has a prominent place in this vision. To promote and facilitate its implementation the Delta Council was founded at the end of 2004. Members of the Delta Council are the provinces of Zeeland, North Brabant and South Holland, as well as the Ministry of Transportation and Water Management, the Ministry of Agriculture, Nature and Food Quality, and the Ministry of Housing, Spatial Planning and the Environment. Municipalities, water boards and interest groups are involved through an advisory group.

First step in the implementation of the vision is the determination of a Delta programme. The Delta programme aims to protect and reinforce the 'delta values' at risk. The programme is being prepared by a so-called 'Programme Bureau', which consists of experts and representatives of the parties which make up the Delta Council. The main challenge of the bureau is the determination of the programme of measures for a sustainable and climate proof development of the Southwestern Delta and its implementation in close cooperation with the parties involved.

In the context of this perspective document, governance is related to creating the proper conditions for a sustainable development of deltas. Good governance should ensure that visions for delta

development are brought into practice through development and adaptation projects. Governance should also provide adequate arrangements for maintenance of infrastructure preventing early deterioration of the infrastructure.

6.1 Multi-level governance of deltas

Lack of cooperation between different levels and sectors of government are a major impediment for implementation of development projects or adaptation strategies. Deltas are mostly governed by multiple governing layers, e.g. international, national, regional and local. The fact that there is no legal entity for deltas adds to the complexity, hence the interest in multi-level governance to overcome these impediments. The trend of decentralization constitutes a major trigger for the strengthening of the governance structure through multi-level governance.

Planning of delta development requires harmonization of different interests. Often trade-offs have to be made between different regions and/or sectors. Given the regional scale of deltas and their role in the development of national economies, there is also the need for (national) coordination of development activities. The actual implementation of a programme of measures requires the cooperation of different levels and sectors of government as well as the private sector, hence the need for a platform for structured communication and negotiation between all parties involved in delta development. The foundation of the Delta Council in the Southwestern Delta of the Netherlands offers a good example of such multi-level governance (see Box 8).

6.2 Linking river basin management and coastal zone management

Since the UNCED Conference in Rio de Janeiro, the link between river basins and coastal areas has been increasingly highlighted in several fora. Two key management approaches have been developed in the post UNCED years to promote sustainable development of river basins and coasts: Integrated Water Resources Management (IWRM) and Integrated Coastal Zone Management (ICZM). The concepts of IWRM and ICZM have been developed rather independently from each other by separate management organisations, frequently with different objectives and modes of operation. Often estuaries and coastal areas were not considered to be part of the river basin. In deltas the coastal zones and river basins do meet. Linking the management of river basins and coastal zones is needed to maintain or improve the ecological integrity and socio-economic viability of coastal and marine areas.

The past ten years have made clear that the advancement of coastal or river basin issues cannot be solved by ICZM and river basin management (RBM) programmes working in isolation. Linked management is often the only realistic way to maintain or improve the ecological integrity and socio-economic viability of the coastal and marine areas. Recently, the linked management of river basins and coastal and marine areas is recognized to be a characteristic feature of an ecosystem-based management.

6.3 Adaptive management to deal with uncertainties

Adaptive management may be defined as an iterative process of optimal decision-making under uncertainty. It has the aim of reducing uncertainty over time via system monitoring. Adaptive management is often characterized as 'learning by doing' although it is more about deliberate experimentation. Examples can be found in the large-scale beach nourishment strategy proposed by the Dutch Delta Committee. This strategy is facing important uncertainties with respect to the effectiveness of large scale sand nourishment as well as the extent of sea level rise. The type of measure, however, lends itself good for adaptation based on the findings of monitoring. The Thames Estuary 2100 project in the UK is another example of adaptive management: the strategy for flood risk management will vary depending on the expectations of sea level rise (see box 9).

Box 9 – **Thames Estuary 2100: flood protection adapting to sea level rise**

Climate change will cause sea levels to rise and will also affect the scale and frequency of tidal surges, but there is uncertainty on the nature of this change. Thames Estuary 2100 is looking at

how to manage tidal flood risk through the century. It includes an assessment of the useful life of the existing defences as well as the development of an understanding of the 'drivers' for change in the estuary (i.e. climate change, urban development, social pressures and the environment). The plan will be adaptable to climate change and to a changing estuary. Depending on the scenario for sea level rise, various types of measures are being considered, including the raising of existing embankments and construction of a new barrier.

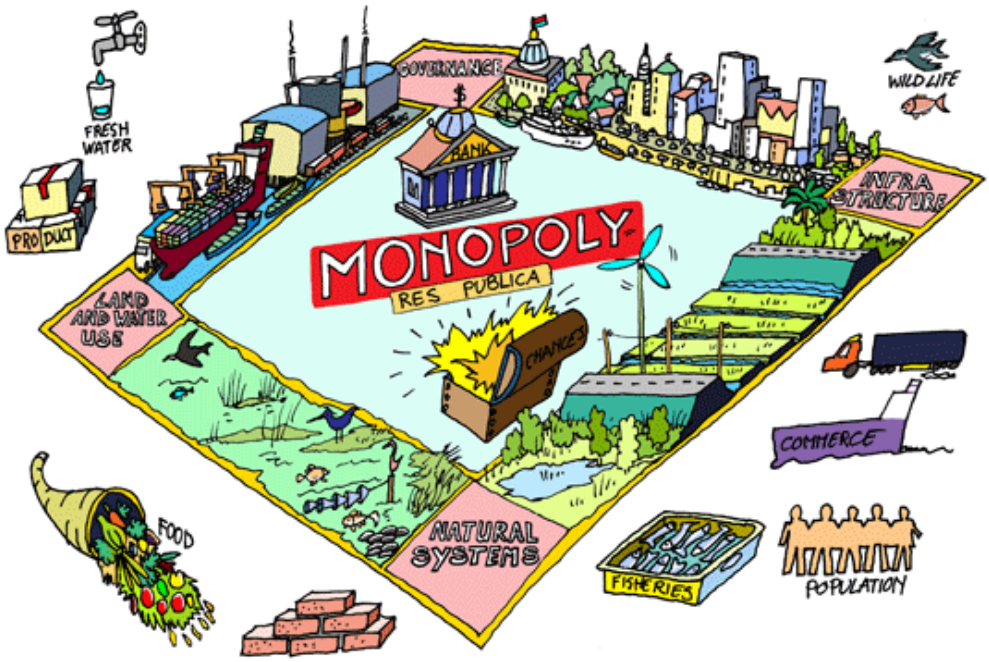
7 Way forward?

The characteristics, which make deltas attractive areas to live and work, are under increasing stress due to population growth, economic development and climate change. The management of delta development has also become increasingly complex, due to - among others - decentralization and privatization. Worldwide concern over a changing climate and environmental degradation has raised the environmental awareness that nature poses limits. A more sustainable development of deltas, however, requires not only acceptance of the limits posed by the natural system but also making use of or even enhancing its enabling conditions. To promote sustainable development of deltas, a clear vision has to be developed on how to best respond to the various drivers of change as well as on how to play along with the various trends in society.

7.1 Delta vision: a shared view on sustainable development of deltas

A shared vision on sustainable delta development should deal with all drivers for change in a delta (population growth, economic development and climate change) as well as with the relevant societal trends (decentralization, privatization, participation, growing environmental concerns and risk aversion). Such a vision should be developed in close cooperation with all parties that have a stake or a say in the development of the delta. A good example of such vision is 'Delta in Sight' which was developed for the southwestern delta of the Netherlands and which presents an integral view on problems and possible solutions for the Dutch Delta waters.

Next, the delta vision should be elaborated into a policy or delta programme. Such a programme should comprise a sensible combination of different kind of responses, including measures for restoration of natural systems, adaptation of land and water use, extension of infrastructure as well as measures to strengthen the governance structure. Establishing the most suitable combination of measures requires



a strategic analysis of the potentials and limitations of the different types of measures. Strategic Environmental Assessment (or Strategic Impact Assessment) may constitute a suitable instrument for the development of the shared delta vision and the associated delta programme.

7.2 Delta technology: innovations in science and technology

Sustainable development of deltas requires innovations in the knowledge of natural systems behavior as well as in the approach to planning and design. For example we should move from an engineering approach to an 'integral approach'. Important 'sources' of innovations are developments in information and communication technology. Advances in sensor and simulation technologies may promote the development of more accurate warning and forecasting systems. These technologies also support the development of local- and global-scale monitoring and diagnostic systems.

7.3 Delta governance: social and institutional innovations

For development of deltas to be more sustainable, it is important to obtain societal acceptance and support for this development. Good governance should promote that shared visions are developed on the basis of sustainable development of deltas. Moreover proper conditions should be created for the actual implementation of such a vision through development projects and adaptation strategies. Governance should also provide adequate arrangements for maintenance of infrastructure to prevent early deterioration of the infrastructure.

Societal trends have to be taken into account in creating these conditions, in particular the trends of decentralization and privatization. Decentralization and privatization may be viewed as autonomous developments. The challenge is to utilize the advantages of both trends, while addressing their undeniable drawbacks. This calls for a selective enhancement of governance structures, reflecting the regional scale, integrated nature and a long-term perspective of delta development.

7.4 Delta dialogue: establishing best delta practices

Sustainable development of deltas is an increasingly complex field which requires the contribution and cooperation of many parties. Although there is no general recipe on how to best deal with many delta issues, it is important to learn from experiences elsewhere. To this end, exchange of knowledge and experiences should be stimulated. Such exchange may take various forms:

- The draft National Water Plan of The Netherlands (December 2008) proposes to set up an active and longstanding cooperation on water safety and water quality with some four delta areas in the world. This cooperation may serve as a vehicle for exchanging experiences in planning and design approaches.
- The Aquaterra Conference has the ambition to develop into a biannual forum on delta and coastal development. The Conference may offer a platform to discuss the various challenges in deltas and the possible approaches to deal with these challenges. Through a process of dialogue, these approaches may be elaborated into best delta practices.

Box 10

Emerging 'best practices' for dealing with delta issues?

Deltas have characteristics in common, but there is much diversity in physical conditions, governance structure and cultural background. Hence, there is no general recipe on how to deal with delta issues. Nevertheless, some broad perspectives may be distinguished on dealing with these issues, such as emerging 'best practices' for deltas, and enhancement of the governance structure as an important component of such practices.

Relieving the pressure on available space

Spatial planning regulation may relieve some of the pressure by redirecting urban development and economic activities to less 'crowded' and/or low risk areas. In cases where spatial planning offers little solace, land reclamation has proven to be an effective way to relieve some of the pressure on space. Land reclamation offers also good opportunities for implementation of the Building with Nature concept meanwhile easily applying new safety considerations. Multifunctional use of areas, e.g. giving a water storage function to nature areas, may further assist in relieving the pressure on space.

Improving resilience of delta areas

Vulnerability of societies to future climate change (such as flood risks, droughts and salinity intrusion) should be reduced, preferably by making societies more resilient. Resilience can be improved by: preparedness, coping strategies and adaptation to changing conditions. This requires a combination of willingness to change, appropriate technology and community participation. Increasing the robustness of infrastructure is another promising way to respond to the increase of the vulnerability of delta areas and the growing aversion of risk.

Securing fresh water supplies

Many deltas in the world currently face water shortages which may aggravate due to climate change and pollution. Adaptation of land and water use will be an important way to respond to these shortages. This may include more efficient water use and/or changes in cropping pattern and fertilization in agriculture. Pollution reduction programmes and establishment of environmental flow requirements for deltas are needed. Their implementation may benefit from involvement of river basin agencies.

Upgrading of ageing infrastructure

Many deltas have irrigation and drainage systems as well as flood protection works, roads, water supply and treatment facilities which require upgrading. Public private partnerships could provide a solution in those cases where farmers, industries and communities directly benefit from these infrastructure investments. But for protection schemes against floods and storm surges other options could be more appropriate, such as introducing financing mechanisms. Rehabilitation of infrastructure offers also opportunities for multifunctional use of infrastructure.

Coastal erosion management

Many deltas experience coastal erosion problems due to a sediment shortage Solutions should preferably include a restoration of the sediment balance. If this is not feasible, sand nourishments are preferred over hard engineering structures. Also other 'Building with Nature' options should be looked into, e.g. mangrove restoration. This is primarily a task for coastal management agencies, who should work closely together with local stakeholders and the private sector.

Biodiversity protection and restoration of ecosystems

Worldwide estuarine ecosystems and biodiversity in deltas are under severe pressure. Effective action must be taken to protect nature areas from local habitat destruction, external disturbance and adverse inputs (pollutants). This requires adhering to the national and international obligations, such as the Habitat Directive, and the Ramsar and Biodiversity Conventions. Biodiversity protection should be effectuated at the local level through cooperation and involvement of all stakeholders. Ecosystems in deltas can be relatively easily restored. An integral approach and early involvement of stakeholders contributes to the success of restoration efforts, The integrity of (modified) estuarine ecosystems may be enhanced through reconnection with rivers and seas.

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Herman van der Most
Deltares, P.O. Box 177, 2600 MA Delft, The Netherlands.
herman.vdmost@deltares.nl

Contributions by Marcel Marchand (Deltares), Tom Bucx (Deltares), Tjitte Nauta (Deltares), Martijn van Staveren (Netherlands Water Partnership)