

# River basins and deltas Water systems and port economies in times of climate change: Rhine, Yangtze and Mississippi

*PBL-TNC-CAUPD Seminar*

*Rotterdam, 11 – 12 October 2022*

Part I: Report

## Preface

This report documents the ideas and exchanges presented at the seminar *River basins and deltas Water systems and port economies in times of climate change*, held in Rotterdam and on-line on 11 and 12 October 2022. It was held precisely then and there in order to coincide with the 150<sup>th</sup> anniversary of the Nieuwe Waterweg, between Rotterdam and the North Sea.

The seminar had been envisaged as an activity of the Special Policy Study (SPS) *River Basins* of the China Council for international Collaboration on Environment and Development. Awaiting the formal start of the SPS, the seminar was held under the auspices of its lead organisations: PBL Netherlands Environment Assessment Agency, The Nature Conservancy (TNC) and the China Academy of Urban Planning and Design (CAUPD). The current report feeds the results of the seminar to the SPS, which is now formally mandated, to the seminar participants and to others who expressed interest.

New challenges in the coming decades – climate change, decarbonisation, demographic, economic and technology developments – will change the rules of the game in river basin management. Port economies and the surrounding deltas are one exiting situation where this will be on display. Very large interests are involved.

A premiss of the seminar was that in order to appreciate the scale and pervasiveness of the potential solutions to this upcoming combination challenges, one needs to study the previous ‘game change’. This previous ‘game change’ occurred typically 150 years ago, involved extensive engineering and effectively subjugated environment conditions to the requirements of the economy and expanding urbanisation. Changes in the coming decades would constitute a second game change and this time around would need to rebalance environment and economy – no longer one dominating the other.

Intellectual inputs by all participants are gratefully acknowledged, as is financial and practical support by the Netherlands’ Ministry of Infrastructure and Water Management and by PBL Netherlands Environment Assessment Agency. On-line participation was facilitated by MWee company; simultaneous translation was provided by Nancy Qin translators.

Presentations at the seminar can be found in a separate document (Part II of this report).

Han Meyer and Jan Bakkes (organizers)

Part I: Report

Contents

Preface ..... 2

Presentations and panel discussions ..... 4

Cross-cutting observations ..... 10

Takeaways for future recommendations by the SPS River Basins..... 14

Annex 1: Seminar programme

Annex 2: Background note

Part II: presentations (distributed separately)

## Presentations and panel discussions

### DAY 1

#### The first 'game change'.

*The creation of our current rivers basins and deltas, starting with the large-scale interventions in the water systems from the 19<sup>th</sup> century until the current state-of-affairs. What did the first game change look like, and to what consequences did it lead? Delta development before the mid-19th century and after. Consequences for current problems, exacerbated by climate change/accelerated sea level rise.*

PBL director **Hans Mommaas** welcomes the participants and outlines background and purpose of the seminar. In particular, attention will be focused on:

- the precise nature of the dynamics and shaping forces of the three delta regions;
- how these dynamics and formative forces were dealt with in the period late 19th century – early 21st century, and what effects this had on the physical conditions of the delta;
- what options are available to use 'nature-based solutions' to create space for the dynamics of the delta and to use it to restore the resilience of the natural system;
- what possibilities there are for combining energy transition, sustainable economic development and new land use patterns with more room for delta dynamics.

By way of overall introduction, **Willem Ligtoet** (PBL principal investigator, international waters programme), explains the need of another game change in the relation between economic development and water systems. Deltas find themselves in a critical state, and this will worsen in the next decades due to plans for 3700 new dams in rivers worldwide, ongoing urbanization, sand mining and other human actions, delivering profit at the short term but increasing problems at the long term. Over and above this comes climate change, for example bringing sea level rise to deltas that are already at risk of shrinking because insufficient sediment is supplied. All over the world, a more sustainable approach of delta regions will result in costs at the short term, but larger benefits at the long term.

The statement of Ligtoet is illustrated and underlined by the three next speakers:

**Jaap Kwadijk** (NL, Deltares) argues that a fundamental transition in Dutch water management started in the 1990s, after two extreme high-water events in the Dutch river area. The program 'Room for the River'<sup>1</sup> (2005 – 2015) and the Delta program (started in 2009) aim to create more room for water and 'working together with water'. This contrasts with the essentially reactive policies of the decades and centuries before. Implementation of this new approach is possible thanks to: (1) a modest but steady budget of 1 billion euro per year); (2) a law, namely the *Delta Act*; (3) a programme with a long time horizon, namely the *Delta Program*; (4) institutional anchoring at Minister-level, by way of the *Delta Commissioner*.

---

<sup>1</sup> A central Program Bureau was appointed by the State. This Program Bureau developed scenarios concerning future expectations of peak discharges. These scenarios lead to the goal to increase the capacity of the whole system to a discharge of 16.000 m<sup>3</sup>/sec (instead of the existing capacity of 12.000 m<sup>3</sup>/sec). Furthermore, the Program Bureau ordered that this goal should be combined with the goal to improve the ecological and spatial quality of the river bed areas substantially. Subsequently, 39 project locations, functioning until then as critical bottlenecks during peak discharges, were appointed to implement these goals in concrete projects. For each project location special project groups were appointed, with local stakeholders, representatives of local interest groups, local politicians, together with hydraulic experts, spatial planners and landscape architects. A special 'quality team', composed of different disciplinary experts, kept an eye on the implementation of the general conditions of the Program Bureau. In this way a workable balance was created between central, general goals and decentral, local involvement. See for more information: Sijmons, Dirk, Yttje Feddes, Fed Feddes, Eric Luiten, 2017, *Room for the River. Safe and attractive landscapes*. Wageningen: Blauwdruk.

However, Kwadijk emphasized that the discussions on climate change and uncertainty concerning sea level rise stimulate the rise of the idea that The Netherlands are not safe anymore for long term economic investments and these perceptions are an economic reality in their own right. In retrospect, decades of high-profile engineering are now looked upon with a mixture of pride (because of effectiveness) and spite (because of the path dependency created). The current question is how to find a new balance between necessary short-term interventions and investments, and a new general belief in long term benefits and sustainability. One reason for 'pride' with the current tools is to have set up a system of periodic review of the Delta Program.

**Li YuanYuan** (PRC, General Institute of Water Resources and Hydropower Planning and Design, vice-president; National Committee of International Water Resources Association, president) shows the importance of a solid analysis and comprehensive approach of (1) water dynamics, (2) socio-economic dynamics and (3) ecological-environmental dynamics. These three types of dynamics are highly dependent of their own driving forces, but they also influence each other. It is important to understand the gigantic scale of these forces as well as their mutual influences. Li argues that it is necessary to develop a new general approach, implemented by new major measures.

*The new general approach* should be based on a solid relation between different scales of action: the scale of the river basin (creating a sustainable water-sediment balance), the delta scale (creating natural buffer areas for peak discharges as well as for fresh water storage during droughts), and the city scale (compact urban and industrial development). *New major measures* should be: guaranteed fresh water supply by creating key reservoirs; flood control by changing flow diversion ratio in the delta; and measures concerning ecological-environmental protection and improvement.

**Justin Ehrenwerth** (USA, The Water Institute of the Gulf) shows the importance of the repair of a sustainable water-sediment balance for the Mississippi delta. Due to narrowing and diking the Mississippi river, sediments don't arrive anymore in the delta wetlands but disappear in the sea, next to the mouth of the river. The result is a dramatic shrinkage of the wetlands during the last century and the loss of their function as a buffer to protect New Orleans against the violence of hurricanes.

The new *Louisiana Coastal Masterplan* provides a repair of a series of distributaries in the delta by breakthroughs in the Mississippi dikes, which will lead to in a renewed sediment and freshwater supply in the delta area itself, resulting in a recovery of the wetlands. Important features of the masterplan are (i) consistent engagement of stakeholders, including major enterprises in the area; (ii) 'structured assessment' of developments and options, as basis for everyone's engagement; (iii) periodic review of the plan.

### **Panel discussion**

**TU Qiyu** (PRC, Shanghai Academy of Social Sciences) emphasizes the need and possibility to combine ecological, economic and spatial ambitions, by referring to the central position of the Shanghai water reservoir in the new Shanghai Metropolitan Masterplan. The lake is an important central feature for fresh water supply as well as for spatial quality and recreation. Also other elements of the main green ecological corridors can play these multifunctional roles. Interestingly, once the city of Shanghai had declared its intention to give this central waterbody an important role in its plan, all adjacent municipalities understood it was in their interest to join the planning process.

**Bart Kuipers** (NL, Erasmus University Rotterdam) emphasizes that the Chinese and Dutch deltas are strongly interconnected with each other by trade flows. However, the question is if this strong relationship will sustain in the future. Kuipers argues that a process of 'deglobalization' has started, putting more emphasis on coherence of national and continental economies and trade flows than on global interconnectedness. While current trade flows in the port of Rotterdam show a dominance of import flows, Kuipers predicts a dominance of export of local industrial products in the next decades. This transition makes it possible to reconsider the land use in the port in relation to necessary environmental and water related interventions.

**Arnoud Molenaar** (NL, City of Rotterdam) is concerned about the lack of directives of central authorities. Currently, spatial planning is at the mercy of 'bottom-up' initiatives, while a water system needs a comprehensive, system-wide approach, especially when it is necessary to combine this with other important societal questions, like energy transition and urban development. He argues that the national authorities should take their responsibilities and take the lead in an integrated water management and spatial planning program.

**Anne Loes Nillesen** (NL, DeFacto Urbanists) addresses the complexity of such a comprehensive planning: Everything is different everywhere. For example, the Dutch water system is not one entity, but a complex, hardly understandable composition of many different polder units, each with a different groundwater level and with its own water patterns and problems, and in the same time all these polders are very dependent from each other. The system of urban patterns shows a similar complexity. This makes it very difficult and also dangerous to rely too much on a top-down approach, especially with initiatives on a grand scale

**Nicole Silk** (USA, TNC) reminds not to forget the social implications of interventions in urbanized deltas. The applicable slogan is: 'not about us without us'. Water related disasters, like floods and droughts, have disproportional impacts for indigenous, black and poor people. Interventions to restore water systems and wetlands should enhance ecosystems and communities.

**Hans Mommaas** closes the day by summarizing four themes which played a main role in the discussion, reflecting the need to rebalance of economy and environment in river basins worldwide

- Attention to the relations between different scales: from local to global;
- We need systemic approaches, based upon understanding the 'behavior' of systems;
- We need integrated and holistic approaches, deliberation based on broader narratives instead of a separation among different disciplinary 'silos';
- We need solid governance models, based on central coordination and direction but leaving space to creative elaboration at a local scale.

Taken together, this means that our considerable and growing knowledge base must be used to support an array of coalitions at various scale levels and places in a timely, transparent and trustworthy manner. That is an intimidating assignment. It underlines that it is useful to look at and learn from concrete cases, as we are doing during this seminar.

## DAY 2

### The second 'game change'

*Approaches to river basin resilience. rebalancing river basin economies and the natural system while both are changing and uncertainties are large. Options and limitations of nature-based solutions. Possibilities to link adaptation to climate change, energy transition and new land use patterns.*

Welcome by **Li Xiaojiang** (PRC, China Academy of Urban Planning and Design, former president). In his opening speech, Professor Li emphasizes the need of regional collaboration in delta regions, with the Pearl River delta as a clear example. From the 1990s to 2010, uncontrolled growth in the PRD has led to ecosystem degradation and disappearance of natural resources and coastlines. Since the 2010s, regional collaboration has resulted in the appointment of a series of nature conservation areas.

Lv Xiaobei (PRC, China Academy of Urban Planning and Design, Deputy Director of the Shenzhen Branch) presented an account of developments in regional collaboration, focusing on the case of the Pearl River Delta. The delta, as so often, features important and fast-growing economic activity, population increase and urbanisation (especially towards the coast) as well as land reclamation. At the same time, the delta houses important nature reserves and is a node on bird migration routes. Environment pressures range from pollution and steadily increasing water temperature to habitat destruction. One key development is growing and successful public opposition to initiatives that would have caused further nature loss.

Encouraged by the national government, regional collaboration is being explored between the governments of Guangdong province, Macao and Hongkong (a ferry ride across the water). Collaboration faces the usual challenges such as differences in standards, approaches to land reclamation and accountability mechanisms. Key ideas include setting up a regional coordination mechanism in environmental impact assessments for the construction of large infrastructure such as ports; and integrating the nature reserves of the delta to form a linked regional conservation initiative.

**Marjolein Haasnoot** (NL, Deltares) is a principal investigator of Deltares, involved in the Dutch Delta program in order to formulate a proper strategy for enhancing the sustainability of the Dutch delta. She emphasizes the need of *combining adaptation* (to already unavoidable future sea level rise) with *mitigation* (by reduction of greenhouse emissions in order to prevent further climate change). This means that we should look for possibilities to link adaptation measures to measures for energy transition and new land use patterns. Climate, ecosystems and human society are coupled systems: this a key to climate-resilient development. Several projects of the last decades show already that adaptation measures can include substantial improvement of the urban landscape: Nature offers significant untapped potential!

Currently, Deltares and the Delta program are exploring four different possible long-term perspectives for the Netherlands in relation to sea level rise: (1) the delta as an open system (with a lot of room for rivers and estuaries); (2) the delta as a closed system (with a closed coastline); (3) a seaward approach (a new artificial coastline in front of the current one) and (4) retreat (moving people and economic activities to higher grounds). Exploring the long-term solution space of each of these perspectives helps: *adaptation pathways* can break adaptation into manageable steps and illuminate lock-in and low-regret investments. Key to is to (i) consider multiple scenarios, including for developments that your government does not control; employ a variety of tools, from story-telling to quantitative modelling and engineering; consider history.

**BAO Qifan** (PRC, Shanghai International Port, former Vice President) reminds of the seven-century history of Shanghai and highlights the expansion of its port infrastructure since the mid-1990s. The agglomeration now measures 3 km<sup>2</sup>. Bao Qifan highlights the land reclamations in the Shanghai region of the last decades. He argues that this land reclamation policy can be considered a 'building with nature' approach, making use of the massive sediment deposits along the shoreline by tidal currents of the sea. During the past ten years, Shanghai International port has expanded to deeper

waters. It will continue to do so, with planned new footholds on two far-out promontories, with 22 m depth.

**Liu Kunyi** (PRC, China Academy of Urban Planning and Design, Deputy Chief Planner of the Shanghai Branch) explains how the Yangtze delta deals with an increased flood risk, as a result of intensification of industrial and urban development in flood prone zones and a degradation of the delta ecosystem, leading to a decrease of the capacity of the natural system to resist typhoon storm surges. Especially the growth of many domestic and industrial ports has contributed to this development. A flood would be catastrophically, because of the presence of a large number of chemical industries along the shorelines. Spatial reorganization of shorelines and ecological restoration of natural shorelines is a central goal: repair of the ecosystem should be combined with creating new public spaces and flood defense along the shorelines.

**Derek Hoeflerlin** (USA, Washington University St. Louis / Derek Hoeflerlin Design) emphasizes the coherence and interdependency of city scale, delta scale and river basin scale by explaining the way of exploiting the Mississippi river basin during the last 150 years and how it influenced the state of the delta and the city of New Orleans. The current state of the river basin can't be changed just like that: the area of the Mississippi river basin is the production area of 40% of the world's food supply. River regulation projects, dams, levees, land reclamations, they all serve the purpose of using the river basin as much as possible for food production and using the river itself for transporting this food. This development had a severe impact on the delta, as also showed by Justin Ehrenwerth at day 1. Hoeflerlin argues that it is not enough to focus only on the delta itself. Despite the enormous scale and the complexity of the river basin, Hoeflerlin shows that it is possible to define a set of different categories of subareas and sub-basins, which creates the possibility to define manageable projects, leading to a restoration of the natural resilience of the river system.

### Panel discussion

**Carline Borest** (NL, Rotterdam Port Authority) argues that we should be aware of the societal importance of ports. For instance, the port like Rotterdam is an essential gateway for the supply of goods and energy for more than 350 million people in Europe. Changing the port system needs very serious considerations. Fundamental change needs time, and can only be organized in a series of steps. We can't control this change completely; we are dependent from many external forces, like Covid, war in Ukraine, cybersecurity, criminality, etcetera. The policy of the Rotterdam Port is based on four pillars: (1) optimizing efficiency and infrastructure; (2) a new energy system; (3) a new raw material and fuel system; (4) sustainable transport. Together it should lead to 55% CO<sub>2</sub> reduction in 2030 and CO<sub>2</sub>-neutral in 2050.

**Bart Kuipers** (NL, Erasmus University Rotterdam) agrees with Borest that change of port areas needs time, but we should be aware that there *will* be change in the next years. The Port Authority Rotterdam itself published a policy document with four possible scenarios; two of them include a decrease of the trade flow through the port of Rotterdam. So, we should be prepared seriously for this scenario, and look carefully to the investments in and around port regions: they are signals which can clarify which scenario will become reality.

**Bas Roels** (NL, World Wildlife Fund) is a bit disappointed by the presentations. He pleads for more radical transformations in the deltas. Most of the presentations are rather positive, but still not radical enough. We don't have time anymore; changes are too little and too slow. 'Adaptation' has become a poisoned word; it has lost its original meaning and is used too often for too small changes. Moreover, he misses the people: Where are the people in the presentations?

**TU Qiyu** (PRC, Shanghai Academy of Social Sciences) agrees with Roels. A delta is water: people can enjoy water! This aspect is underexposed in the lectures. More emphasis on water as an attractive public amenity will contribute to a broad public support of radical changes in water systems.

Moreover, port cities represent a specific form of social capital [term introduced by the report drafters – JB]. They are more than transportation hubs. Port cities offer valuable, long-lived social and economic networks whose default orientation is way beyond the city – worldwide, for the examples the seminar is discussing. This value should get more attention in any analysis of rivers and deltas.

On the matter of globalisation or de-globalisation and its effect on port city economies, Professor Tu observed that of the top ten global ports by volume, seven are on China's East seaboard. This alone suggests that a key avenue forward is perhaps not increased expansion, but specialisation and upgrading.

**Anne Loes Nillesen** (NL, DeFacto Urbanists) refers to the presentation by Marjolein Haasnoot, talking about the need to explore the long-term solution space of different perspectives of the Dutch delta. She emphasizes the importance of 'research by design': exploring the long-term solution space is not only a matter of scientific calculations, but should be a process of interaction among creative design, scientific research and innovative engineering. The 'radical transformations', suggested by Bas Roels, only can be realized with this type of interdisciplinary collaboration.

**Han Meyer** gratefully refers to the call by Bas Roels for creativity and innovation. He closes the discussion by thanking all speakers and panel members.

## Cross-cutting observations

*Some elements figured in multiple presentations, panel reflections and discussions. They can be grouped as follows.*

### GAME CHANGE

After one and a half century dominance of economy on natural water systems, the general conclusion is that this dominance has led to irresponsible distortion of natural systems and cannot be continued. Creating **a new balance** between on the one hand **economic driven land use** and on the other hand **the dynamics of natural water systems** should get absolute priority. This means a radical revision of the dominating approach and use of river basins and deltas. **Building with Nature** should lead to a restoration and improvement of biodiversity, and to a 'working together' with the dynamics and forces of natural processes of water systems, including currents, waves, erosion, sediment transport, siltation, etcetera.

An example of the start of the start of this game change is the new policy in the Mississippi delta, aiming to create a series of cuts in the dikes alongside the river, in order to provide the wetlands of the delta with sediments and fresh water of the river. This will turn the processes of erosion into enforcement and extension of the wetlands. Restoration of these wetlands, which function as a buffer to decrease the violence of hurricanes, is essential to maintain New Orleans. In recent history, dike construction alongside the river was meant to improve the conditions for navigation and agriculture. In the next future, dike construction will also be meant to improve the conditions for ecological restoration.

Another example is the experiment with 'double dikes' in The Netherlands. Letting seawater in the strips of land between the dikes will result in a natural elevation of the land by sediment deposits. Recent Chinese examples include the emphasis on green and blue infrastructure in urban development, and the cleaning up and renaturing of shorelines of the Yangtze.

### PERCEPTION

It should **not be taken for granted that things will stay as they are**. Specifically, Li Yuanyuan sketched an array of powerful changes with lasting impetus, including forces in the physical domain, demography and spatial organisation, and measures in relation to safety and security.

After Views notably differ on **the kind of ports required in the next decades**. Will there be ongoing globalisation and bulk trade? Will there be de-globalisation and more emphasis on goods with high added value? Will there be no equivalent of current flows of fossil energy carriers, or, alternatively, even larger volumes, consisting of sea-borne hydrogen? All current scenarios of container goods for the Port of Rotterdam indicate some degree of shrinkage in volume; arguments regarding Shanghai differed: ongoing growth versus upgrading and specialization only. Either would perhaps offer opportunities for synergy in addressing various challenges in the basin as a whole, but in different ways.

Stories of all three ports (in fact, regional groups of ports) depicted **important spatial vectors**: new harbour facilities at new locations and further out to sea (Shanghai, at least in one of the views presented); hydrogen-production further out to sea and high-value import/export based further inland (Rotterdam, at least in some of the views presented).

Perceptions by market parties, including perceptions of climate risk and impending mitigation efforts, **can force the hand of local governments**. Two speakers from the NL pointed to this

phenomenon. Arnoud Molenaar, of the city of Rotterdam, alluded to the considerable in-house analytical capacities that enable investors and large enterprises to set their own course, if it takes the government too long to reach consensus.

## SCALE

Many speakers supported the notion that the **scale and pervasiveness of past and current changes** illustrates the scale and pervasiveness of upcoming changes and the necessary responses.

A number of examples illustrated the insight that the ongoing and required changes play at a **different scale than conventional strategic planning**. The planning of the Great Shanghai Metropolitan Area placed strong emphasis on blue and green infrastructure. This, in turn, made local governments around Tai Hu Lake join the planning process of their own accord, as they understood the benefits of being involved. Current comprehensive planning for the Mississippi started at the lower reaches and then, logically, extended towards its middle reaches. Traditional river management in The Netherlands, although working with international river commissions, essentially behaved as if rivers began where they entered this small country, for the last segment of the river's journey towards the sea.

Aside from spatial and temporal dimensions, the **scale of invested capital** is significant and was often referred to during the seminar. Obviously, the scale of past investments points to the longevity of traditional business interests. In turn, this makes it necessary that the powers representing past and future investments engage in current discussions around the future of river deltas such as the three deltas highlighted at the seminar. Interestingly, large enterprises did engage in, and sign up to, Louisiana's Coastal master Plan. In contrast, similar power players in the Rotterdam/Rhine delta seem underrepresented in the public discourse, while at the same time, no doubt, much corporate research is going on.

## INVOLVEMENT AND EMPOWERMENT

Pleas were tabled to involve **power players and affected groups and interests beyond the incumbent**. Principles were mentioned. For example, one such principle is "not about me without me". A related plea is for creativity to give future generations of people and businesses a voice.

Marjolijn Haasnoot underlined work of IPCC Working Group II, reminding the seminar that the **traditional distinction** between climate system, human system and ecosystems will no longer hold in view of the challenges for the next decades. Interestingly, through biophysical logic and systems thinking, this arrives at similar perspectives as 'ecological civilisation'.

**Examples of institutional mechanisms** were mentioned, although not discussed in great detail. Interestingly, 'Structured Decision Making' served well in the Mississippi delta. Strategic Environment Assessment would be the equivalent in The Netherlands and in China, but was not portrayed – probably because it requires a policy initiative for a start. Hans Mommaas, current DG of PBL and key note speaker at the seminar, will soon chair the Netherlands Commission for Environment Assessment.

Large investors seem, so far, **almost invisible in discussions** about redesigning Rhine delta and rethinking the role of the port of Rotterdam. In contrast, large enterprises are part of The Louisiana Coastal Master Plan.

## THE PEOPLE

Several speakers asked ‘where are the people’? A real and radical game change of economy and water system only can be reached when it will get broad public support. This, in turn, is only possible if authorities, scientists, designers and engineers can show what the new, attractive aspect will be of the ‘new game’. It should lead to an environment in which water plays a main role as an issue of pleasure and joy. Li Xiaojiang referred to successful protests of the public to an extension of Shenzhen Bay cruise ship sea tour route, because of serious concerns on the consequences for the ecosystem and the quality of the landscape. Bas Roels referred to comparable public protests against plans for dike-enhancement in the Dutch river area in the 1980s. The latter was the start of a new way of thinking on the balance of safety against flooding, economic goals and quality of life, resulting in the ‘Room for the River’ program.

The role of the central lake in Greater Shanghai is a good illustration, explained by Tu Qiyu. The lake is important for water storage and fresh water supply in the region, but also for recreation and leisure.

This makes it necessary to develop a new story, a new *narrative* on the role of water and water systems in the urbanized world.

## LONG TERM VISION AS A BEACON

The importance of a **solid, government-sponsored vision** for the long term was underlined by many. Jaap Kwadijk, for example, praised as a reason for pride to have a nationally accepted long-term expectation combined with a mechanism of review every few years. He described it as a key achievement in the development to finally move beyond policies that were in essence reactive.

On how to deal with the inherent uncertainties of the future, within the envelope of expectations, four key insights emerged.

It was argued, but not generally supported, that in view of the large uncertainties **starting with small interventions** is a wise strategy.

**Nature based solutions** were often mentioned, typically as one category within a large toolbox. Looking back to the past 150 years, it is obvious that the technologies of hard engineering required decades of experience in order to mature. That much time is not available in addressing climate change and the implications of decarbonisation. Therefore, it is important to (i) moderate expectations and (ii) speed up learning from any NbS applications as much as possible.

In exploring future strategies vis-a-vis climate change in delta areas, it is key to **anticipate a range of scenarios** – not just a most likely scenario or an accepted baseline. This requires considerable homework and critical analysis. But it can be done and informs periodic decision making, in view of ‘branch points’ --- orderly switching from one strategy to another, if necessary. Marjolijn Haasnoot presented an example for the Rhine-Meuse-Scheldt delta.

In order to be able to define a proper strategy, based upon the possibilities of the scenarios, **design explorations** are necessary. Derek Hoferlin (USA) and Anne Loes Nillesen (NL) showed that these explorations, using the creative power of experienced designers, can reveal unexpected possibilities and lead to new discoveries of the potential qualities of the river- and delta territories. It leads to an awareness that the ‘game change’ of economy and

water system not only is necessary to avoid catastrophes, but also can lead to new perspectives of attractive and desirable environments.

### **REMARKABLE INTEREST**

On a general note, the level of interest in this topic proved remarkable --- for this seminar as well as for preceding and subsequent conferences on 'redesigning the delta'. From individual reactions, the impression of the organizers is that comprehensive view and almost-timely call for ceativity have a broad appeal.

## Takeaways for future recommendations by the SPS River Basins

1. **Rebalancing** is necessary between the requirements for human activities ('economy', for short) and the constraints posed by the natural system. Until one or two centuries ago, the natural system – river dynamics, for example – dictated the possibilities for human settlements and economic development. Then, in most situations typically 150 years ago, hard engineering successfully turned this around and harnessed rivers and wetlands, subjugating natural systems to the requirements of 'the economy'. In the next decades, multiple simultaneous developments will challenge this paradigm.

Instead, creativity from many disciplines will be needed in order to rebalance these mega-systems, so that river systems and economic systems mutually support each other rather than one side constraining and dominating the other. Mobilizing this creativity should be supported with material resources, government guidance as well as the thinking power of all interested parties.

2. **Understanding systems** is at the basis of wise management of socio-environment systems, such as river basins. This calls for systematic analysis of deep drivers, such as physical changes, demographic and economic changes, environmental impacts and response strategies. Frameworks for this have been tabled at the seminar and are worthwhile following up by regional think tanks and cooperation bodies.
3. Wise and effective governance and management of river basins requires **a government-backed authoritative policy**. For international basins, the same applies, but in international term. This authoritative policy can be a combination of
  - A. **Scenario building**: scientific explorations of possible futures, based upon plausible, or maximum plausible, change in climate indicators as well as possible developments in economy, demography, transport and urbanization, and identification of key biodiversity assets. Scientific institutions should have the key role in defining these scenarios.
  - B. **Defining a strategy**. After public and political deliberation on the possible consequences of the scenarios, the overarching authority of the river basin territory should define a desirable and feasible strategy, based on the knowledge of the scenario studies and desirable developments of society and the natural system.
  - C. **Integral approach**. Strategies concerning water safety and fresh water supply should be combined and integrated with strategies concerning energy transition, sustainable spatial planning and improvement of the ecosystem.
  - D. **Defining and implementing projects**. A strategy can only be implemented by defining a series of concrete projects in the river basin and delta, which can be considered keys for reaching the goals of the defined strategy.
  - E. **Involvement of the public**. Regional and local authorities, stakeholders and representatives of residents should be able to contribute to the exact definition and implementation of the projects.

Scenario building, strategy-definition, integrated approach, defining projects and involvement of the public should be interconnected, leading to a continuous process of evaluation and adjustment of scientific knowledge, political goals and practical instruments. The Dutch 'Room for the River' program (2005-2015) can be considered an example.

4. **Mechanisms exist to engage stakeholders and parties affected.** For example, Structured Decision Making and Strategic Environment Assessment. What are interesting experiences, in view of the important and profound changes on the horizon?
5. Contrasting views exist on the **type of international ports required in the future.** Given the dominant position of the ports in the basins considered by the seminar (New Orleans, Rotterdam and Shanghai), it seems important to have discussion about the desired and probable development in the open. Based on the seminar discussions, the following observations can be made
  - each the developments discussed, for each port, means very distinct spatial developments – East, West, towards promontories, etcetera;
  - a number of interventions responded to the advent of regional overcapacity and suggested a potential for upgrading and or specialisation – implying possibilities for redesigning the delta;
  - miraculously absent from public discourse around the future of mega ports, at least in some regions, are the power players with large investments at stake.

One suggestion for the SPS is to stage a CCICED round table on this, mapping these potential developments, possibly jointly with the WEF.

6. A key observation from IPCC WG II needs to be echoed by the SPS: the climate system, nature and the human living environment should be considered as **one system** – not three separate systems. Therefore, policies and governance should be coordinated, if not integrated.
7. Thus, a **new general approach** is advocated – most extensively, by Li Yuanyuan -- acknowledging and quantifying critical elements such as sediment flows, flows of fossil energy carriers, and climate change. Importantly, such a new general approach works at three levels of scale simultaneously: the basin scale, the delta scale and the city scale.

=====

## Annex 1: Seminar programme

Day 1: afternoon of 11 October 2022, Central European Summer Time

### ***The first 'game change'.***

*What did the first game change look like, and to what consequences did it lead? Delta development before the mid-19th century and after. Consequences for current problems, exacerbated by climate change/accelerated sea level rise.*

14:00 CEST

**Hans Mommaas** (PBL, director-general) -- Welcome and kick-off (15 mins)

14:15 CEST

#### Introductions:

**Willem Ligtoet** (PBL) - worldwide quantified overview (15 mins)

**Jaap Kwadijk** (Deltares) -- Rhine-Meuse delta (15 mins)

**LI YuanYuan** # (General Institute of Water Resources and Hydropower Planning and Design, vice-president; National Committee of International Water Resources Association, president) -- Yangtze delta (15 mins)

**Justin Ehrenwerth** # (Water Institute of the Gulf, CEO) -- Mississippi delta (15 mins)

15:15 – 15:30 PAUSE

15.30 CEST

#### Panel:

**Anne Loes Nillesen** (Defacto, founder), with a focus on spatial implications (5-10 mins)

**TU Qiyu** # (Shanghai Academy of Social Sciences), with a focus on social and spatial implications (5-10 mins)

**Arnoud Molenaar** (City of Rotterdam, Chief Resilience Officer), with a focus on urban resilience (5-10 mins)

**Bart Kuipers** (Erasmus Centre for Urban, Port and Transport Economics), with a focus on port economy implications (5 – 10 mins)

**Nicole Silk** # (TNC, Global Director for Freshwater Outcomes), with a focus on environmental and social implications (5-10 mins)

16:15 CEST

Discussion Moderated by **Hans Mommaas**

17:00 CEST closure; refreshments

Day 2: afternoon of 12 October 2022, Central European Summer Time

***The second game change***

*Approaches to river basin resilience. rebalancing river basin economies and the natural system while both are changing and uncertainties are large. Options and limitations of nature based solutions. Possibilities to link adaptation to climate change, energy transition and new land use patterns.*

14:00 CEST

**LI Xiaojiang #** (China Academy of Urban Planning and Design, former president) -- Welcome and kick-off (5 mins)

14:05 CEST

Introductions:

**LV Xiaobei (CAUPD)** – developments in regional collaboration (15 mins)

**Marjolein Haasnoot** (Deltares) -- Rhine-Meuse delta (15 mins)

**BAO Qifan #** (Shanghai International Port, former Vice President) -- Yangtze delta (15 mins)

**LIU Kunyi (CAUPD)** – sustainable use of Yangtze river banks (10 mins)

**Derek Hoferlin** (Washington University in St Louis) -- Mississippi delta (15 mins)

15:15 – 15:30 PAUSE

15.30 CEST

Panel:

**Anne Loes Nillesen**, with a focus on spatial implications (5 mins)

**TU Qiyu #**, with a focus on social and spatial implications (5 mins)

**Bas Roels** (WWF Netherlands) with a focus on natural environment aspects (5-10 mins)

**Bart Kuipers**, with a focus on port economy implications (5 mins)

**Carline Borest** (Port of Rotterdam) with a focus on port development strategy (5-10 mins)

16:15 CEST

Discussion, conclusions

Moderator: **Han Meyer**

16:45 CEST

Concluding remarks

**Han Meyer**

17:00 CEST closure; refreshments

-----  
# On-line

## Annex II: Background note

River basins and deltas. Water Systems and Port Economies in Times of Climate Change: Rhine, Yangtze and Mississippi. Seminar by PBL, TNC and CAUPD, 11- 12 October 2022

### *Introduction: not just climate change*

River basins and especially delta areas are currently confronted with climate change, which leads to changing conditions and to greater vulnerability to flooding, salt intrusion, but also to problems such as drought and freshwater shortages. However, it would be a mistake to look for the causes of these problems in climate change alone. In the search for effective long-term strategies, the changes in the physical conditions of river basins and delta areas, especially caused by human hands during the last century and a half, must also be considered. Although there were good reasons for these changes (economic development, urban growth and prosperity), the downside is that the resilience and dynamism of the natural system in these areas has declined sharply. The effects of climate change, such as rising sea levels and increasing peak discharges of rivers, can have a greater impact on river basins and delta areas due to this reduced resilience (PBL 2018).

The seminar that PBL, TNC and CAUPD want to organize in the autumn of 2022 is based on the observation that the transformation of river basins and delta areas during the 19<sup>th</sup> and 20<sup>th</sup> centuries can be considered a 'game-change': the game changed from a dominating role of the dynamics of natural systems to a dominating role of man-made land-use patterns, manipulating the natural systems with an overload of engineering (cf. PBL 2021). The central hypothesis, which we want to explore more carefully, is that we need a second game-change, which gives priority to restoring the dynamics and resilience of natural systems in river basins and delta areas. The working conference aims to discuss and determine whether such an approach is possible and effective. The question is what consequences such an approach has/could have for economic and urban development, and how this approach can be combined with strategies for energy transition and making our economies, cities and landscapes more sustainable.

To get a clear understanding of the current, second game-change, it is necessary to discuss also the first game-change: in order to understand the deep consequences and character of such a game change, and to learn from it.

A concrete proposal for the structure of the working conference follows in the last paragraph. First we will discuss the backgrounds and character of the first and second 'game changers'.

### *The dynamics and formative power of the delta's natural system*

The world of the 21st century is facing the enormous challenge of a complex combination of adaptation to climate change, of preventing an acceleration of climate change through energy transition, and of restoring biodiversity and the resilience of natural systems.

This complex combination of tasks occurs to an extreme extent in the catchment areas of the major river basins and in particular the delta areas, where the rivers flow into the sea and where the greatest economic and urban growth has taken place worldwide over the past 150 years and is still ongoing. The major rivers and especially their deltas are at the heart of the logistics process of production, transport and consumption of modern industrial societies.

It is true that this development has a long history. Nevertheless, we can say that the last century and a half, from the mid-19th to the end of the 20th century, is the period in which most river basins and delta areas experiencing a 'boost' of large-scale transformations that served to accommodate economic and urban growth. The Rhine, Yangtze and Mississippi deltas are striking examples.

These transformations not only resulted in a reclassification and functional change of the territory of the delta, but also had a strong influence on the dynamic and formative character of the delta. Deltas are the result of dynamic processes of rivers and sea, with regular and irregular changes in currents, tides, wave action, sediment transport and sedimentation, vegetation, wind, precipitation. Most deltas owe their present shape largely to the way in which these processes took place in the last 12,000 years, after the last Glacial Period. The large amounts of sediment that were brought in by rivers and the sea and subsequently became overgrown with vegetation, led to dynamic processes of land formation (Kleinhans 2010; Jarriel et al. 2021).

The dynamic nature of the natural system of deltas gave rise to three main characteristics of deltas: first, extraordinarily rich ecosystems. According to some, deltas and estuaries contain the richest ecosystems, with the most 'ecosystem services' of any ecosystem in the world (Costanza et al. 1997). Deltas include important intersections of migratory fish and migratory birds, which use deltas for foraging, spawning, and breeding.

Second, the dynamics of the delta led to the continuous formation of new (wet)land, which increasingly served as a protective buffer in the coastal landscape. It is true that these processes were erratic and in various places they also led to erosion and flooding of land. But the net result over the centuries was that the land in the delta grew with or even grew faster than the sea level rise (Seybold et al. 2007).

Third, the dynamics of water and sedimentation lead also, with some regularity, to structural changes in the course of the main river discharge and thus in the shape of the delta. The development of the Mississippi Delta shows several 'delta lobes', which are the result of changes in the course of the main river discharge since the last Glacial Period (Campanella 2006; Blum, Roberts 2012; Giosan, Freeman, 2014). These changes occur once every few hundreds or thousand years and are the result of the silting up of the estuary by sediment supply and deposits by the river itself and the sea. Now as the riverbed of the main discharge starts to silt up, it starts to act as a blockage, and the water tries to find another, easier way to the sea, especially in the case of huge peak discharges. The development of the Rhine/Meuse delta shows a similar process. The main discharge of the Rhine has moved south in several steps over the course of 12,000 years (Vos 2011).

These processes continued in most deltas until about the mid-nineteenth century, when large series of major interventions are started that radically change the hydrological system and the spatial structure of the deltas.

*The first game change: From dynamic system to controlled mechanism*

Two important developments during the nineteenth century are responsible for a fundamental 'game change' in the systems of river basins and delta: technology and the rise of nation-states. These two developments created the conditions for the era called 'the Anthropocene' ([www.britannica.com](http://www.britannica.com) ; Sijmons 2014).

The technological revolution of the nineteenth century includes the invention of the steam engine and later the electric and gasoline engine, and the discovery and use of coal and later oil and gas as energy sources. The new energy sources and technical equipment created the necessity as well as the possibility of major adjustments to the water systems of deltas and rivers. The steam engine allowed for larger ship sizes; the larger ships required deeper waterways, which were made possible by steam and diesel-powered dredgers. Riverbed narrowing also took place on a large scale, resulting in deep waterways on the one hand and more available land for agriculture and urbanization on the other. The waters that mainly serve as a transport corridor are separated from the land by high dikes, where urban, agricultural and industrial development can take place. Due to intensive drainage of the swampy lowland, subsidence is occurring behind the dikes, increasing the vulnerability to possible flooding.

The new nation-states of the late 18<sup>th</sup> and 19<sup>th</sup> century created the institutional conditions for the large-scale, cross-regional interventions in the river basins, like Rijkswaterstaat (National Water Management Agency) in the Netherlands and the US Army Corps of Engineers in the USA (O'Neill 2006; Lonngest et al., 2014; Meyer 2017).

The deltas of the Rhine, Yangtze and Mississippi all three show this development. It is true that there are many differences between the characteristics of these three deltas, but essentially the development process of each of these three deltas has the same characteristics. If you compare the maps of the three deltas from ca. 1850 with those of 2022, you will not only see a spectacular increase in urban and industrial land use, but also the consequences of large-scale river rectifications and normalisations, of new land reclamations, of countless waterworks such as new canals, dikes, dams, locks, of roads, railways, pipelines. We also see what has disappeared: many tens of square kilometres of intertidal areas: wetlands, mud flats, salt marshes, sandbanks, beaches, dunes.

What took place during this period, which began with the deployment of the first steam-powered ships, dredgers and drainage pumps, and has in fact still not ended, can be called a first fundamental game-change. With the rise of the fossil fuel based industrial society, compared to the previous

centuries, a fundamental change of the game has taken place, with new players, new rules and new outcomes.

The net result is that, during the last century and a half, delta areas have been drivers of explosive economic growth and prosperity. Not only have the delta areas themselves become centers of economic growth and wealth, but this development has also been crucial for the hinterland. The Mississippi has become the main transportation corridor of the United States since the mid-19th century; 90% of what is shipped across the Mississippi and its tributaries goes to or comes from ports in the Mississippi Delta (O'Neill 2006). The Rhine basin is the economic artery of Europe, or the 'Blue banana' according to the French geographer Roger Brunet (1989). For the development of the Rhine into a Blue banana, the transformation of the Rhine delta into an efficient transshipment and distribution center played a key role (Klemann, Wubs 2013).

In China, the Yangtze Delta and the Pearl River delta are the two most densely urbanized regions of the national territory; together they are responsible for 40% of the GDP of China ([www.thinkchina.sg](http://www.thinkchina.sg))

However, the flip side of this development is that the delta has changed from a natural system to something resembling a mechanical system. The entire water system of the river and delta has taken the form of an industrial machine. This also creates the illusion that rivers and their deltas can be controlled and monitored like an industrial machine. The toll that must now be paid for this illusion is threefold.

Firstly, we must note that the 'mechanisation' of the delta has led to a large decline in biodiversity. In some deltas, the specific features of the delta ecosystem have largely or even almost completely disappeared. Not only did this lead to a considerable impoverishment of fauna and flora in the delta landscape itself; this also has major implications for life on Earth in a much larger context. With the disappearance of large parts of delta nature, an essential link in the food chains of countless birds, fish, shellfish and plants in our rivers, seas and oceans has disappeared (<https://www.worldwildlife.org/habitats/wetlands>).

Directly linked to this is the second major problem: the disappearance of a large part of the formative capacity and thus of the resilience of the natural system of the delta. Instead of processes of siltation, land accretion and soil raising, other processes have come to dominate: erosion, subsidence, ever higher water levels in the river mouths and a saltwater tongue penetrating deeper and deeper into the land. And insofar as there is still a supply of sediment, as the most important building block for land formation, it is dredged away to keep the rivers at their depth for shipping (Ericson et al. 2006; Tessler et al. 2015; Hoitink et al. 2020).

Thirdly, the attempt of optimal control and fixation of the river and delta has led to the natural process of displacement of the estuaries appears to have come to an end. We emphatically state

that this process '*appears* to have come to an end', as we see that water management authorities over the past hundred years have been forced to build more and more engineering works in the river system in order to maintain the existing main drainage riverbed. In the Mississippi Delta, a series of dams, spillways and flood ways have been created around the connection between the Mississippi and Atchafalaya Rivers to counteract the natural system's tendency to divert the main drainage to the Atchafalaya River. Nevertheless, it is feared that the time will come when this tendency will no longer be countered, with disastrous consequences for the city of New Orleans and the surrounding area (Barnett 2017; Day et al. 2014). In the complex network of river courses of the Rhine/Meuse delta, a series of interventions have also taken place that counteract the tendency of the Rhine and Maas rivers to discharge more and more water via the Haringvliet and force this discharge out to sea increasingly via the Nieuwe Waterweg near Rotterdam (Vellinga et al. 2014).

More than fifty years ago it became clear that maintaining this approach to the river system is harmful and unsustainable. The first large-scale protests against the loss of river and delta nature date back to the 1960s and have led to the first major adjustments in the Netherlands, such as the cancellation of the complete closure of the Oosterschelde and the construction of the Markerwaard. Not coincidentally, the report for the Club of Rome, *The Limits to Growth* (1972), was published during this period.

Although the main aim of these protests and changes was to prevent the disappearance of the delta nature, the need for a fundamental change in economic growth was already hinted at as a guiding principle in the development of natural landscapes (Buelens 2022). The American landscape architect Ian McHarg introduced an analysis and design method for wetland landscapes in the 1960s, in which he introduced the need to make a distinction between slow (climatic, geological, geomorphological, hydromorphological) change processes and faster, often human-initiated, change processes such as infrastructure development and urbanization (McHarg 1969). His position was that it is important to take good account of the slow processes, to offer sufficient space for this, and to adapt infrastructure and urbanization accordingly. In practice, he saw exactly the opposite happening, with disastrous results. This method was later elaborated in the Netherlands and became known as the 'layer approach', which was advocated in various government memorandums of the 1990s and 2000s (Meyer 2017).

The relevance of this layer approach became apparent from the 1990s, when the first signs of climate change emerged and it became clear that the channelled river courses did not have sufficient capacity to discharge the increasing amounts of melt and rainwater due to climate change. The Dutch *Room for the River* program (2005-2015) was the first important implementation of the layer approach. Restoration of the river ecosystem was combined with the task of increasing the discharge capacity of the rivers and restoring and strengthening the resilience of the natural system (Sijmons et al. 2017).

Also, in and around the Mississippi Delta, the first ideas for major modification of the river drainage system date back to the 1990s and gained momentum after the 2005 Hurricane Katrina disaster. The wetlands of the delta have been subject to severe erosion since the 1930s. As a result of the

channelling of the Mississippi river, all the tributaries that fed sediment- and nutrient-rich freshwater into the wetlands were dammed. The wetlands form a buffer that dampens the force of hurricanes. Erosion of these wetlands is catastrophic to the survival of the city of New Orleans (Campanella 2006; Barnett 2017).

However, with the latest insights and predictions regarding climate change and sea level rise (IPCC 2022; Deltares 2018), the question is whether the changes in the Rhine/Meuse delta, Mississippi delta and Yangtze delta are sufficient. The restoration of nature and especially the restoration of the dynamics and the shaping capacity of the deltas requires a significantly more radical 'game change'.

*Towards a second game change: restore the dynamics and resilience of the natural system in combination with energy transition*

The need of a new 'game change', giving priority to nature-based solutions in delta areas, has already been addressed frequently (Costanza 1997; Temmerman, Kirwan, 2015; Day et al. 2014). However, the major task in delta areas is twofold: to restore the resilience of the natural system and provide room for its dynamics, and to shape the transition from fossil to non-fossil energy sources. This means a combination of maximum mitigation as well as adaptation.

One of the main driving forces behind these changes in deltas is the port and shipping industry. In many cases, and certainly also in the deltas of Mississippi, Rhine and Meuse and Yangtze, the transshipment, storage and processing of fossil fuels plays a central role. Port development and shipping were the basis for the radical spatial and hydrological transformation of the delta, but also for the fact that the deltas have become central hubs in an economic system based on fossil energy sources. Due to the large amount of space required and the many infrastructural systems, the port and shipping system also appears to be the most difficult to change. Because of this strategic role of ports and shipping in the delta areas, and to make the discussion more concrete, the consequences for ports and shipping will have to be explicitly discussed when discussing possible future prospects for these delta areas.

Discussions are ongoing in both the Netherlands and the Mississippi Delta about the most effective and desirable strategies for making the delta resilient to sea level rise. In the Netherlands, three approaches seem to emerge in the Sea Level Rise Knowledge Programme: (1) continue the development of the past century, with even stronger civil engineering works and on a larger scale, (2) a 'retreat' of cities and economic activity to higher grounds, and (3) more room for restoration and reinforcement of the natural system, in the expectation that this will also lead to processes that make the delta less vulnerable to sea level rise and higher peak discharges (Ligtvoet et al. 2009, 2011; Haasnoot et al. 2019).

Also, in the Mississippi Delta there seems to be a balancing of comparable alternatives, as was reflected in the design competition 'Changing Course' (<http://changingcourse.us/>).

The first option (reinforcement of the existing system) only seems to cause more problems in both deltas in the longer term. Maintaining an increasingly large-scale 'armor' to protect low-lying territory will encounter increasing technical, managerial and financial problems. It seems much too early for the second option ('retreat'); hopefully it doesn't have to come to that. To prevent this option, something will have to be done in the delta areas.

That is why, during the working conference, we propose to seriously examine the possibilities for a fundamental game change based on a new priority for space for the natural system.

*The seminar October 11 – 12, 2022*

The foregoing argument can be summarized with the following figure:

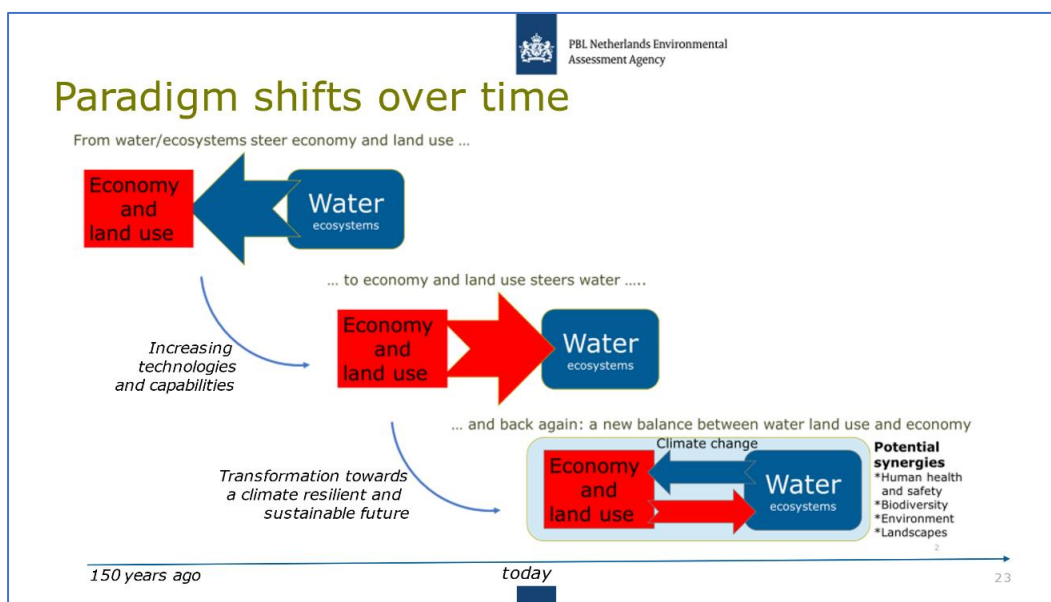


Figure 1. (Ligtvoet et al. in prep.)

The transition of the upper relationship diagram between water and economy to the middle diagram represents the first game change: from a system in which water is leading, and economic and urban development is following, to a system in which economics and urban development are dominant, resulting in adaptations of the water system. The transition from the middle relationship diagram to the bottom one reflects the current task: a new 'game change', leading to the implementation of a hybrid system in which the water system on the one hand and the economy and land use on the other hand find a new balance.

The seminar 'River basins and deltas - Water Systems and Port Economies in Times of Climate Change: Rhine, Yangtze and Mississippi' aims to investigate to what extent the idea of the first and second game change is relevant for these three river basins and deltas, and in what sense it can give direction to a new approach for a new balance between economic and environmental development.

In particular, attention will be focused on:

a) the precise nature of the dynamics and shaping forces of the three delta regions; (b) how these dynamics and formative forces were dealt with in the period late 19th century – early 21st century, and what effects this had on the physical conditions of the delta; (c) what options are available to use 'nature-based solutions' to create space for the dynamics of the delta and to use it to restore the resilience of the natural system; (d) what possibilities there are for combining energy transition, sustainable economic development and new land use patterns with more room for delta dynamics.

These four questions will be addressed on both days by three experts on the three deltas. Subsequently, a panel of four experts in the field of water management, urban development, ecology and port economics will reflect on the potential consequences of the proposed strategies for these four fields.

## **References**

- Barnett, James F., 2017, *Beyond Control. The Mississippi River's New Channel to the Gulf of Mexico*. Jackson (MS): University of Mississippi.
- Brunet, Roger, 1989, *Les Villes 'Européennes'*. Rapport pour la DATAR (Délégation à l'Aménagement du Territoire et à l'Action Regionale). Paris: Reclus.
- Buelens, Geert, 2022, *Wat we toen al wisten. De vergeten groene geschiedenis van 1972* [What we already knew then. The forgotten green history of 1972]. Amsterdam: Querido.
- Campanella, Richard, 2006, *Geographies of New Orleans. Urban fabrics before the storm*. Lafayette: Center for Louisiana studies.
- Costanza, R., R. d'Arge, R. Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, et al. 1997. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387: 253–260
- Day, John W., G. Paul Kemp, Angelina M. Freeman, David P. Muth (editors), *Perspectives on the Restoration of the Mississippi Delta. The Once and Future Delta*, Dordrecht Heidelberg New York London: Springer
- Deltares, 2018, *Mogelijke gevolgen van versnelde zeespiegelstijging voor het Deltaprogramma. Een verkenning* [Possible consequences of accelerated sea level rise for the Delta Program. An exploration]. Delft.
- Ericson, Jason P., [Charles J. Vörösmarty](#), S. Lawrence Dingman, Larry G. Ward, Michel Meybeck, 2006, 'Effective sea-level rise and deltas: Causes of change and human dimension implications'. [Global and Planetary Change](#) 50/1–2, 63–82

- Giosan, Liviu, Angelina M. Freeman, 2014, How Deltas Work: A Brief Look at the Mississippi River Delta in a Global Context, in: John W. Day, G. Paul Kemp, Angelina M. Freeman, David P. Muth (editors), *Perspectives on the Restoration of the Mississippi Delta. The Once and Future Delta*, Dordrecht Heidelberg New York London: Springer, 29-32.
- Haasnoot, Marjolijn, Ferdinand Diermanse, Jaap Kwadijk, Renske de Winter, Gundula Winter, 2019, *Strategieën voor adaptatie aan hoge en versnelde zeespiegelstijging. Een verkenning* [Strategies for adaptation to high and accelerated sea level rise. An exploration]. Delft: Deltares.
- Hoitink A. J. F., J. A. Nittrouer, P. Passalacqua, J. B. Shaw, E. J. Langendoen, Y. Huismans, D. S. van Maren, 2020, Resilience of River Deltas in the Anthropocene, *Journal of Geophysical Research: Earth Surface* 125/3: open access.
- IPCC, 2022, *Climate change 2022: Impacts, Adaptation and Vulnerability*. New York: United Nations.
- Jarriel, Teresa, John Swartz, and Paola Passalacqua, 2021, Global rates and patterns of channel migration in river deltas, *Proceedings of the National Academy of Sciences (PNAS)* 118/46: 1-8
- Kemp G. Paul, Clinton S. Willson, J. David Rogers, Karen A. Westphal, S. Ahmet Binselam, 2014, Adapting to Change in the Lowermost Mississippi River: Implications for Navigation, Flood Control and Restoration of the Delta Ecosystem, in: John W. Day, G. Paul Kemp, Angelina M. Freeman, David P. Muth (editors), *Perspectives on the Restoration of the Mississippi Delta. The Once and Future Delta*, Dordrecht Heidelberg New York London: Springer, 51-84.
- Kleinhans, Maarten G., 2010, Sorting out river channel patterns, *Progress in Physical Geography* 34/3: 287–326
- Klemann, Hein A.M., Ben Wubs, 2013, *River Dependence Creating a Transnational Rhine Economy 1850-2000*, Rotterdam: Erasmus University.
- Ligtvoet, Willem, Joost Knoop, Bart Strengers, Arno Bouwman, 2009, *Flood protection in the Netherlands: framing long-term challenges and options for a climate-resilient delta*. The Hague: PBL.
- Ligtvoet, Willem et al., 2011, *Climate adaptation in the Dutch Delta. Strategic options for a climate proof development of the Netherlands*. The Hague: PBL
- Lonnquest, John, Bert Toussaint, Joe Manous Jr., Maurits Ertsen, 2014, *Two centuries of experience in water resources management. A Dutch – U.S. Retrospective*. Alexandria (VA): Institute for Water Resources, US Army Corps of Engineers, and Rijkswaterstaat, Dutch Ministry of Infrastructure and the Environment.
- McHarg, Ian, 1969, *Design with Nature*. New York: Natural History Press.
- Meyer, Han, 2017, *The State of the Delta. Engineering, urban development and nation building in The Netherlands*. Nijmegen: VanTilt.
- PBL (2018), *The Geography of Future Water Challenges*. The Hague: PBL.

- PBL (2021), *Navigating Rivers and Deltas towards a Sustainable Future*. The Hague: PBL Netherland Environmental Assessment Agency.  
<https://themasites.pbl.nl/future-water-challenges/river-basin-delta-tool/>
- O'Neill, Karen, 2006, *Rivers by Design. State power and the origins of U.S. flood control*. Durham (NC): Duke University Press.
- Seybold, Hansjörg, José S. Andrade, Jr., Hans J. Herrmann, 2007, Modeling river delta formation, *Proceedings of the National Academy of Sciences (PNAS)* 104/43: 16804-16809
- Sijmons, Dirk, 2014, Waking up in the Anthropocene, in: Brugmans, George, Jolanda Strien, *Urban by Nature. International Architecture Biennale Rotterdam*. Rotterdam: IABR.
- Sijmons, Dirk, Yttje Feddes, Fed Feddes, Eric Luiten, 2017, *Room for the River. Safe and attractive landscapes*. Wageningen: Blauwdruk.
- Tessler Z.D., C. J. Vörösmarty, M. Grossberg, I. Gladkova, H. Aizenman, J. P. M. Syvitski, E. Foufoula-Georgiou, 2015, 'Profiling risk and sustainability in coastal deltas of the world'. *Science* 349/638 pp. 638-643
- Vellinga N.E., A.J.F. Hoitink, M. van der Vegt, W. Zhang, P. Hoekstra, 2014, Human impacts on tides overwhelm the effect of sea level rise on extreme water levels in the Rhine–Meuse delta. *Coastal Engineering* 90: 40–50
- Vos, Peter, 2011, *Atlas van Nederland in het Holoceen* [Atlas of the Netherlands in the Holocene], Amsterdam: Prometheus.