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Panorama New Netherlands

Editors: Jos Timmermans and Joep Storms

How can the Netherlands adapt to sea level rise on the long term: maintain, advance or retreat? This article compares the results of seven plans and designs from a diverse group of scholars and professionals that offer very different answers to this question. This diversity broadens the options, which is vital in this stage. Both problem solving and design approaches are shown to be worthwhile, when grounded in coastal, landscape, and ecological dynamics as well as visions of the Netherlands in the far future.

By Eric-Jan Pleijster, Geert van der Meulen, Jos van Alphen, Marjolijn Haasnoot, Ferdinand Diermanse, Kim Cohen, Philip Minderhoud, Jasper Leuven, Kari-Anne Gerritsen, Michaël van Buuren, Elma van Boxel, Kristian Koreman, Negar Sanaan Bensi, Joep Storms, Ranee Leung and Jos Timmermans.

1. Introduction

What if sea level rises with X meters? This question has inspired urban, landscape and spatial designers, and delta managers and academic researchers alike to design radical adaptation strategies for the Netherlands. This all started when the then supposedly high-end sea level rise of 0.85 m in 2100 (Delta Programma, 2015) was dwarfed by the 2016 results of Antarctic ice sheet models that estimate Global Mean Sea Level rise to range from 0.26 to 2.43 m in 2100 and from 0.50 to 15.52 m in 2300 (DeConto & Pollard, 2016). While the Paris-agreed max 2.0-degree rise in global average temperature transfigures into the red queen of climate mitigation, the initial interest in extreme sea level re-designs for the Netherlands becomes serious what-if explorations.
In line with the Adaptive Approach of the Delta Program, the new information also triggered the Dutch government to start the **Kennisprogramma zeespiegelstijging** (IenW et al., 2019). Its results will serve as input for the next 6-year evaluation of the Delta Program strategies and delta decisions in

2026. Companies, knowledge institutes and NGOs contribute their experience and knowledge to this research program. The program aims to:

1. reduce uncertainty surrounding sea level rise and the collapse of the Antarctic ice sheet
2. establish the tenability of the current strategies for flood protection and fresh water supply
3. develop and implement a method to signal SLR in a timely and reliable way
4. explore long term options to adapt when required and keep these options open for the future
5. design a complementary governance strategy towards these long term options when needed

This article contributes to the fourth objective of the Research Program Sea Level Rise. It is based on independent work of mostly interdisciplinary academic research groups and LOLA landscape Architects. It highlights the commitment of scientists and the private sector to contribute their curiosity, research and innovative capacity to climate proofing our country.

This paper discusses seven plans and designs. Many more plans and ideas exist that could have been included in this paper. Almost all of them are collected in the **KustWiki** prepared by Deltares for the Delta Program. Many of these ideas are rooted in a technical idea or innovation for coastal protection. They offer valuable ideas that inspire, complement and bolster spatial redesigns but are not a redesign for the entire country. Some of them such as "**De mooiste en Veiligste Delta 2010-2100**" [West8, TNO, Rijkswaterstaat, InnovatieNetwerk, Ruimtelijk Planbureau, Unie van Waterschappen, 2007] and "**Zee_delijkheid - het land verwatert en de zee verlandt**" [Annick van Tilburg, TU Delft 2003] operate at the same level compared to the plans and designs included in this paper.

Our selection is a "pragmatic stratified sample" from the available re-designs, where the strata are the diverse perspectives that can be expected from physical geographers, spatial designers, spatial planners, delta managers and engineers. Pragmatic here refers to the possibility to contact the people behind the plan and their current participation in the extreme sea level rise discourse. The aim of this selection is to explore different perspectives and their consequences for the resulting plans and designs. We are consciously comparing apples and oranges to broaden our knowledge and ideas in this stage of the adaptation process.

In this contribution, we compare the results and focus on the designs and plans. We reflect on the consequences of the objectives and guiding principles for their outcomes. First the original developers present and characterize their redesign: Plan B NL2200 [A] by LOLA Landscape Architect Eric-Jan Pleijster, New Netherlands [B] by TU Delft master student Geert van der Meulen, Solution Space for Adaptation to High Sea Level Rise in the Netherlands SLR Solutions [C], by Jos van Alphen, Marjolijn Haasnoot and Ferdinand Diermanse prepared by Deltares for the Delta Program, VN Plan B [D] by Kim Cohen of Utrecht University, Drowned Delta [E] by Philip Minderhoud, Jasper Leuven, Kari-Anne Gerritsen of Utrecht University's Water, Climate & Future Deltas hub, NL2120 A nature-based future for The Netherlands [F] by Michaël van Buuren of Wageningen University & Research, and Delta Plan X [G] by Elma van Boxel, Kristian Koreman and Negar Sanaan Bensi of ZUS and Joep Storms, Geert van der Meulen, Ranee Leung and Jos Timmermans of TU Delft.

2. Plans and designs

A. Plan B NL2200

Eric-Jan Pleijster | LOLA Landscape Architects

Starting point for Plan B for the Netherlands is to have a diverse set of strategies available to adapt as a country to climate change and sea level rise. Currently raising and fortifying dikes and storm-surge barriers to increase flood risk protection seems the most obvious way forward. This strategy however does have serious technical, economical and societal consequences and limitations.

The world's best protected delta might not be able to adapt to the extreme sea-levels that could occur when the Paris climate agreements fails to sufficiently limit global temperature rise. The failure of the international climate change policy arena is unfortunately something that needs to be considered as likely to happen, while adapting dikes, dams and polders to climate change effects does have its limits.

Spatial visions and planning are required to develop the required range of alternative strategies to adapt to climate change. In the beginning of this century, The Netherlands had a well-developed and internationally recognized tradition of spatial planning operational. Because of decentralization, institutional possibilities for spatial planning at the national level have however been minimized: the development of spatial visions for the entire country was judged as not desirable, and a waste of time and money during the financial crisis.

Plan B NL2200 [A] first of all underlines the need to restore the Dutch tradition of spatial planning at a national level, in the face of adaptation to climate change and high-end sea level rise. It is a first exploration of a strategy to adapt to higher sea levels under an extreme - but plausible - scenario: +2 meter in 2085, +3 meter in 2100 and +6 meter in 2200 (De Winter et al., 2017). Dikes, dunes, dams and storm-surge barriers will not be able to handle these extreme conditions.

Plan B envisions a Netherlands without dikes. It does not focus on engineering dikes and dams, or constructing gigantic landfills with fossil materials from natural landscapes. Plan B uses accelerated sea level rise to leverage the rebuilding of The Netherlands by using the driving forces of nature. In this future, the Dutch would live on a logical location: above sea level, not below it.

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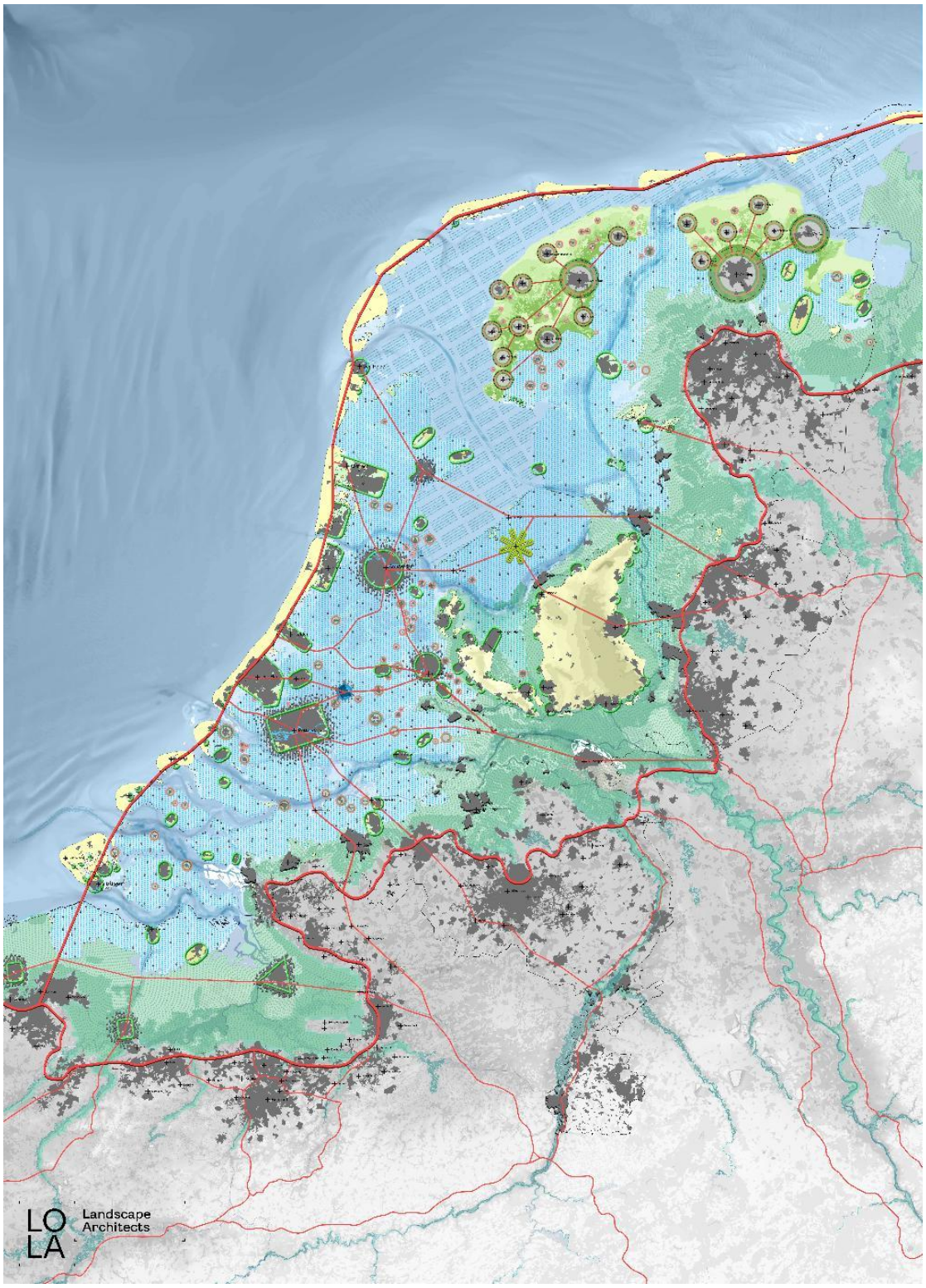
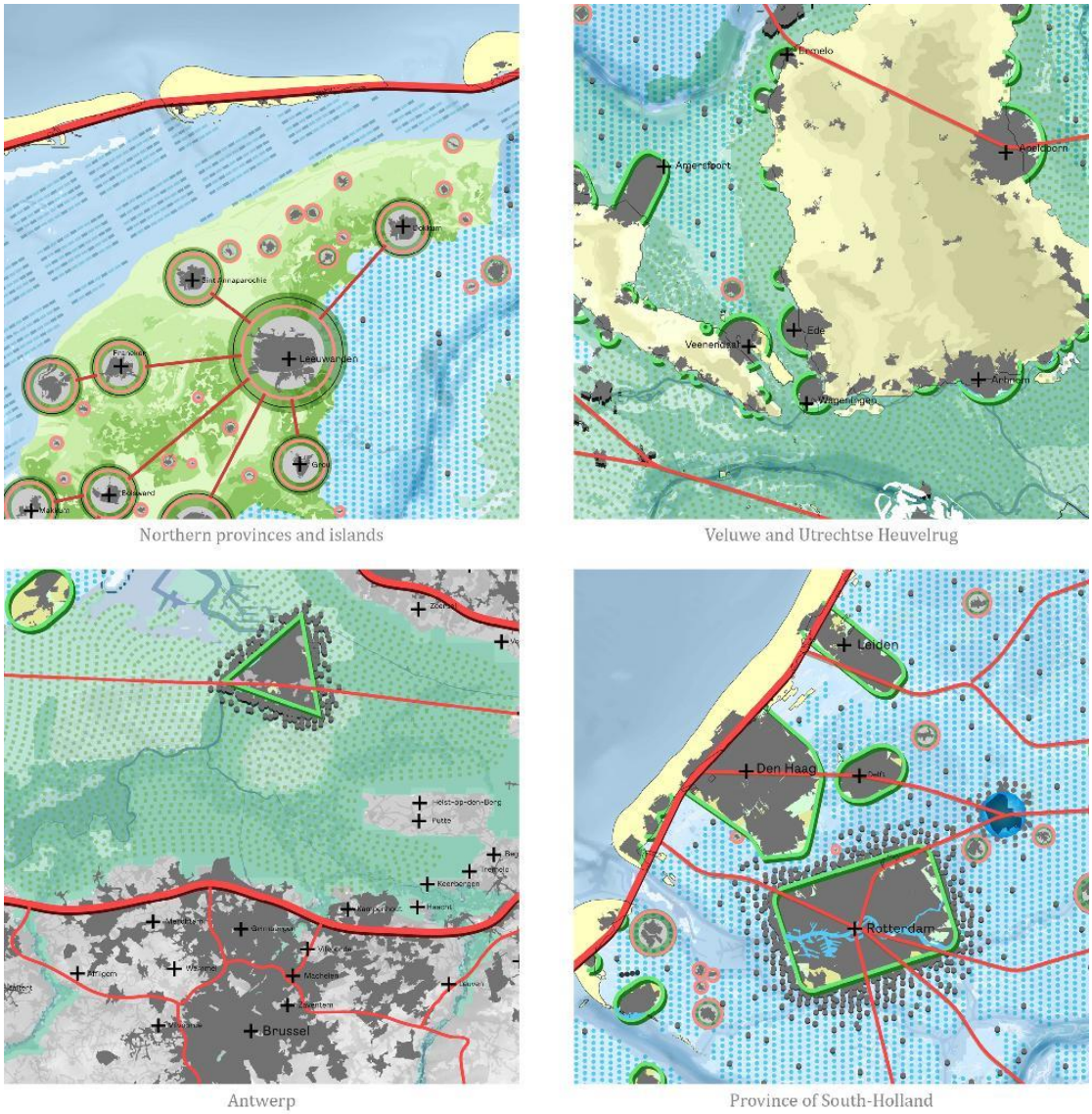


Figure A1 - Plan B NL 2200 Entire Country

Living above sea level means a shift of the coastline to the east of the country. The inhabitants of the lower parts of the country will have to move themselves and all facilities, infrastructures, and employment opportunities to the east. Along this eastern coast, the economic heart of the country will be reconstructed.

The remainders of the west coast will be maintained and strengthened to develop a marine lagoon with the protected remnants of the historic cities and villages. In accordance with their tradition of water management, the citizens of 'Waterland' will develop the lagoon for residential areas, fisheries, aquaculture, recreation, nature and energy.



Northern provinces and islands | Veluwe and Utrechtse Heuvelrug

Antwerp | Province of South-Holland

Figure A2 - Regional crops of Plan B NL 2200

Plan B NL2200 [A] is not a defeat, although plan B might look alarming at first sight. It pictures a positive outlook for the future of the Netherlands, in which the Dutch deal with water in a different way. Even when Plan A (realizing the Paris agreements) fails or proves to be not sufficiently effective, the Netherlands can continue to exist by living with water and building with nature. The Dutch might even come out stronger.

In the end, Plan B is not a spatial plan, but an agenda. It is a bottom-up appeal to rethink the spatial future of the Netherlands. A roadmap for the future of the Netherlands needs to be developed from a

wide set of integrated strategies including spatial opportunities. This roadmap is needed not only to adapt to climate changes and sea level rise, but also to deal with nitrogen deposition, decline of biodiversity, housing, and the quality of life in our urban areas. The Netherlands has shown that is has been able to plan and build its own future. Now is the time to build on this tradition.

B. New Netherlands

Geert van der Meulen | TUDelft

This research is a mapping exercise. The guiding principle for this exercise is the continuity of the historic narrative of the Netherlands. Relevant elements of this narrative are the tradition and history of flood defence, population dynamics, core economic areas, nature reserves and landscapes, and cultural and heritage values. The historic narrative and its physical and societal results give the Dutch part of the Rhine delta an intrinsic value and contingent suitability for future coastline shortening or coastline dynamising. To facilitate this mapping exercise, first the geographical distribution of the flood risk management elements, nature, rivers and water bodies, economy, population and heritage of Current Netherlands are presented. Second, the challenges of Current Netherlands evoked by sea level rise are discussed. A structured mapping exercise is then applied to lead to New Netherlands: a safe and prosperous place for the Dutch to live in, continuing their struggle with The North Sea under a sea level rise of 2 to 10 meters.

In anticipation of extreme sea level rise, the historical Dutch process of coastline shortening can be carried through. Alternatively, the Netherlands can embark on a more natural attitude to flood risk management, based on the idea of 'living with a dynamic coastline'. The opportunities of both coastline shortening and coastline dynamism are examined through a mapping exercise. This mapping exercise follows the basic proposition that the Netherlands are a result of its historical socio-economical, cultural and physical narrative; the *longue dureé* of its centuries long social and physical interaction within its geographical context. This historical narrative gives the Dutch Rhine delta an intrinsic value and a contingent suitability for either coastline shortening or coastline dynamising. The geographical distribution of the flood risk management elements, nature and geomorphology, rivers and water bodies, economy, population and heritage are used as an underlying tabula for this exercise. Although the distribution of artefacts and networks for transport, energy, water supply and sanitation are likewise sensitive to flooding, these are considered more dynamic, adaptive and controllable than flood risk management infrastructure, protected nature, rivers and lakes, the economy, population and heritage. To permit this exercise, the complexity of the Netherlands is reduced to a level of abstraction that enables distinct prioritisation. The design of New Netherlands, we assume, harmlessly disregards interconnected parts of the system.

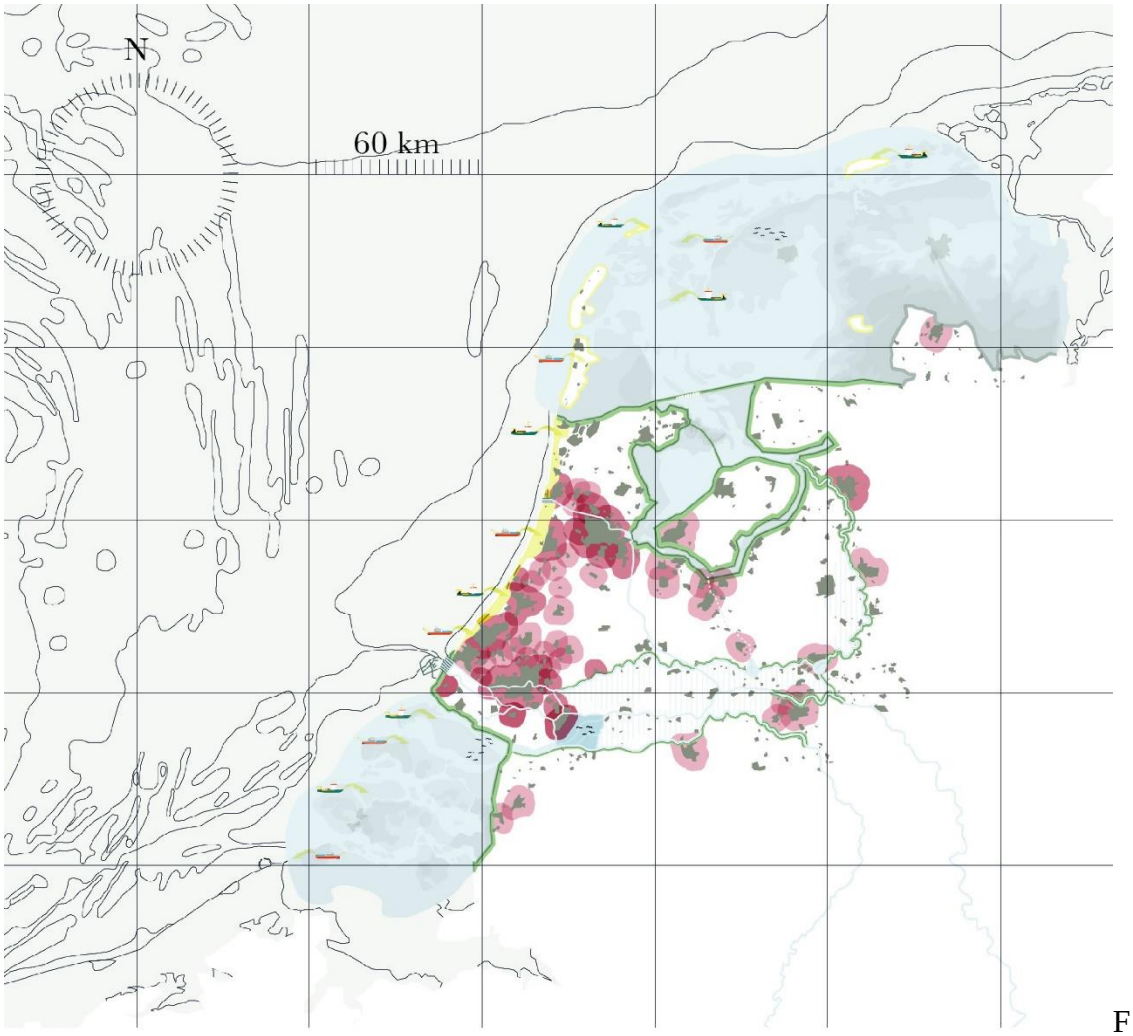


Figure B1 - Living in New Netherlands: distribution of urban and more rural areas in New Netherlands.

The mapping exercise based on priorities and spatial dynamics resulted in a visualisation of regional priorities that direct change under extreme sea level rise. A vision on New Netherlands that entails both continuation and disruption: continuation of the process of coastline shortening and disruption to a dynamic coastline.

New Netherlands is shaped to efficiently secure the Netherlands as a prosperous nation living with water and at the same time struggling to defeat it (Figure B2). The emphasis on the Dutch population, its economic assets, cultural traditions and heritage (Figure B3), its natural bodies (Figure B4) and water systems structure the country's new contour by harmoniously applying coastline shortening and coastline dynamising. The dichotomy results from analysis of reasonable and beneficial investments and the importance of existing and underlying functions, systems and patterns of the country. Figure (Figure B1) gives an impression of the distribution of urban and rural areas in New Netherlands, still structured largely by current river alignments.

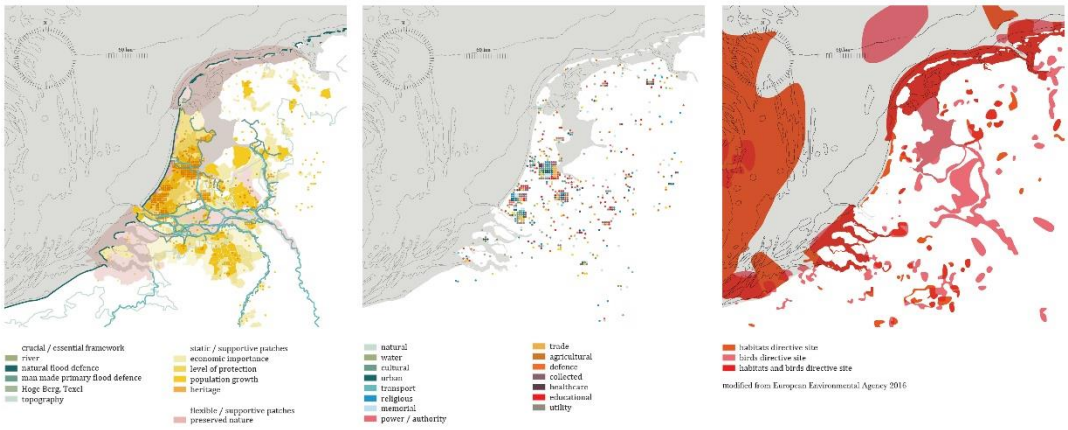


Figure B2 Figure B3 Figure B4

Figure B2 - Spatial priorities: aggregated visualisation of regional priorities in population distribution, flood defences, nature reserves, rivers and water bodies, cultural heritage, economy, topography and geomorphology, that direct change under extreme sea level rise

Figure B3 - Cultural heritage: combined natural, water, cultural, urban, transport, religious, memorial, power/authority, industrial, trade, agricultural, defence, collected, healthcare, educational, and utility heritage.

Figure B4 - Natura 2000 areas

New Netherlands is capable of providing safety with a sea level rise of 2 to 10 m. It decreases the flood risk management challenge through shortening the Dutch coastline from 880 km to 580 km. It offers space to the Wadden Sea, the Southwest Delta, and their natural dynamics under sea level rise. Natural processes of erosion and accretion allow for the revision of the dredging policy for the North Sea and coastal nourishment can continue on the shortened coastline to stabilize the dunes and dikes and sustain some of the Wadden Islands. New Netherlands provides safety for the important economy of the Randstad (Holland). A river discharge regulation work in the east of the country controls the division of discharge of river water and works together with the fresh water storage capacities of the Markermeer, Biesbosch and rivers. The new coastlines, the Randstad and higher parts of the Netherlands can anticipate the relocation of around 1.7 million Dutch people as a reinforcement of the current population trends.

The New Delta Programme

The realisation of the new contour of the country and the relocation of 1.7 million of the countries inhabitants is challenging. Notwithstanding its emphasis on continuity in natural areas, urban centres, heritage and economic strengths, resistance will rise. In an attempt to make the transformation process towards New Netherlands more tangible, the regions of the current Delta Programme are transferred to regions more applicable for the New Netherlands under scenarios of extreme sea level rise. The New Delta Programme embraces a transformative approach to governance.

C. Mapping the solutions space to high-end sea level rise for the Netherlands

Jos van Alphen | Delta Program
Marjolijn Haasnoot and Ferdinand Diermanse | Deltares

As the implications of a high and accelerated sea level rise will be large and may require additional and possibly alternative solutions than currently considered in the Delta Program, a study was committed to Deltares to map the solution space to adapt to high-end sea level rise of 2 to 4 meters (Haasnoot, Diermanse, Kwadijk, De Winter, & Winter, 2019). The solution space was assessed on their technical and societal feasibility and adaptivity. In addition, possible adaptation pathways to reach end-states of the solution space were explored as well as necessary or low-regret actions for the next 20 years.

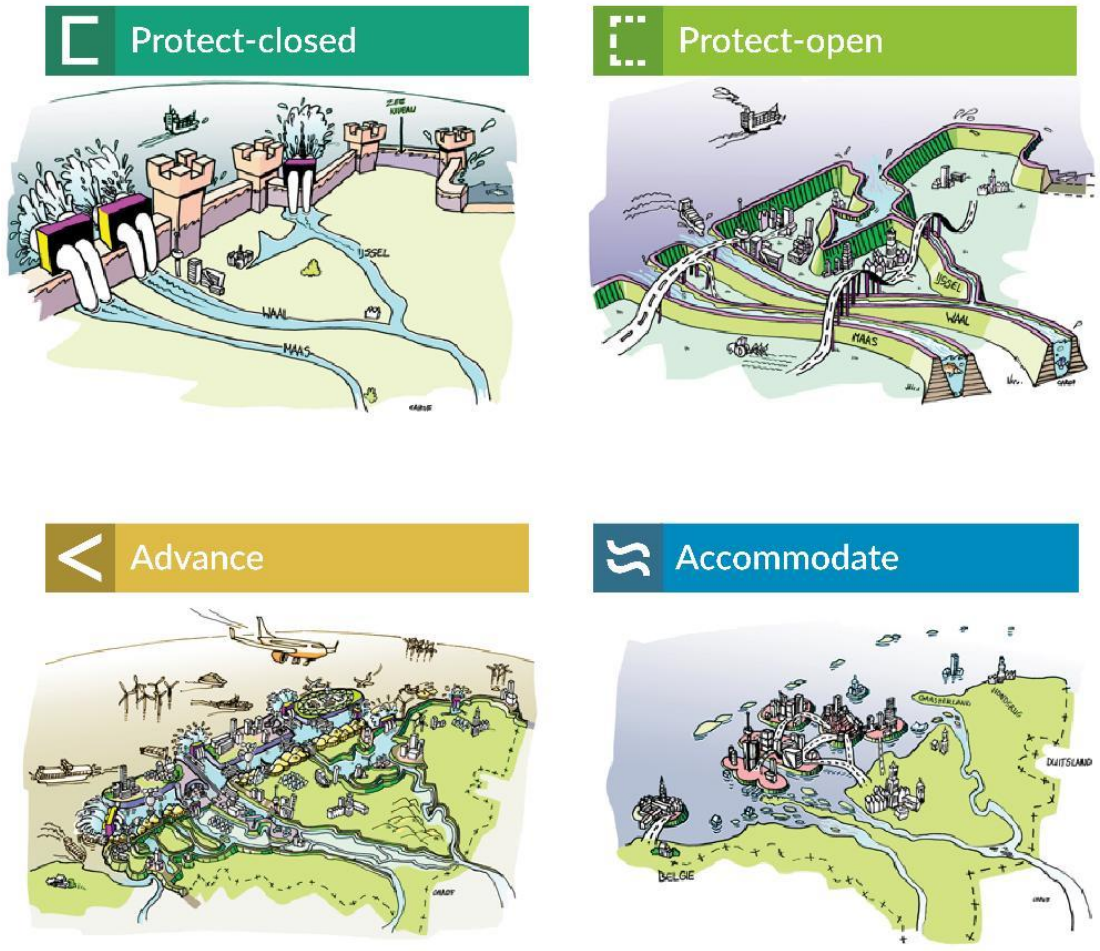


Figure C1 - The solutions space. Cartoons developed by Carof for Deltares.

Four corners of the solutions space for the Netherlands were identified building upon the different types of responses to sea level rise as described by the IPCC as a starting point (SROCC 2019, IPCC,

1990), and the plans and ideas that have been proposed by numerous individuals, institutes and consortia in recent years. For the Netherlands, this resulted in:

- Protect-closed: protect the coast against flooding and erosion through hard or soft measures such as flood defences, sand replenishment or wetlands. River arms are closed (with dams or sluices).
- Protect-open: same as above, but some rivers stay in open connection with the sea.
- Advance: create new, higher and seaward-located land to protect the delta against flooding and create a manageable waterbody in front of the present coastline.
- Accommodate: reducing vulnerability to the consequences of a higher sea level rise: water or salt tolerant land use areas (e.g. buildings on piles or crop use), raising land, spatial planning and / or inland migration.

Figure C1 illustrates archetypes of the corners of the solution space. An inventory of around 180 plans and ideas for adaptation to sea level rise and coastal development can be found on this website: **http://nladapt.deltares.nl**.

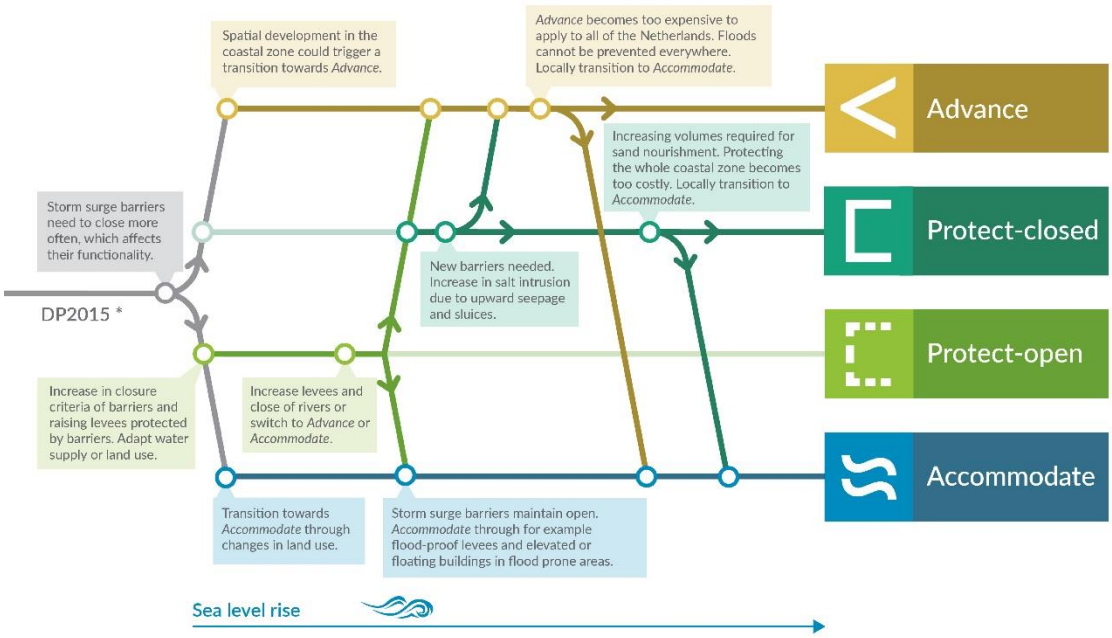


Figure C2 - Solution space and pathways for adaptation to high sea level rise in the Netherlands. *) Decisions and strategies presented in the Delta Program 2015. By Deltares.

Figure C2 presents possible adaptation pathways and strategic choices lead to the four corners of the solution space. The current strategy, which is mostly “Protect-open” can change into a strategy of “Protect-closed” through a limited number of interventions, like closing estuaries by sluices and pumping stations. Another option is to choose the "Accommodate" strategy at some locations; e.g. provide more room for water and allow regular flooding while at the same time take actions to limit flood damage. Spatial developments in the coastal zone may possibly trigger to switch to "Advance"

either from the “Protect-open” or “Protect-closed” strategy. Based on the analysis, the following strategic choices for the Dutch delta were identified. For the estuaries: have them open or closed; for the rivers: trade-offs between river pumping, storage, drainage and distribution; for the coast: hard or soft protection, maintain or relocate; and for the western polders: keep them fresh or allow salinization.

Choosing between the solution directions is not yet necessary. To keep future options open, further research is needed into strategic choices and use of space of the Dutch delta. In addition, the Netherlands needs to continue to experiment with innovations, stay alert, and monitor developments and insights on future climate change and sea level rise to be able to initiate large-scale adjustments in time. All the solution strategies identified require transformative change, that cannot unilaterally be directed by government. Connection of these transformations to ongoing transitions in other domains can bolster adaptation to sea level rise. In addition, it is deemed important to secure the adaptation vision in an agreement, law, fund, or commission.

The study is a follow-up to Appendix B of the Delta Program 2019 "Possible consequences of accelerated sea level rise for the Delta Program" and is part (track 4) of the Sea Level Knowledge Program of the Ministry of Infrastructure & Water Management and Delta Commissioner staff. Deltares has carried out this exploration on behalf of the Delta Commissioner, with contributions from various experts from TU Delft, Utrecht University, Wageningen University, VU University Amsterdam, University of Twente and the Netherlands Environmental Assessment Agency.

D. The Low Countries in 2300 under extreme sea-level rise

Kim Cohen | UU Geosciences Physical Geography

The sketch map of Figure D1, was a captioned figure in a 2019 **long-read article** in Vrij Nederland (Schuttenhelm, 2019) on the rising need to seriously consider high-end sea level rise in long-term planning. The article quoted Dutch global sea level rise experts on getting the message across that rates of rise matter, also for engineers and architects that tend design on given heights of expected sea levels. In high-end scenarios, the rates of change become several meters per century. Such shortens planning horizons, reduces feasible mitigation options, raises logistic challenges of all our current water management strategies, all suggesting to move to a Plan B of some form.

The sketch map visualised extreme-scenario impacts on the Dutch delta as very different to what we are used to and have ever coped with (Figure D1). The visual is not one of new designs, strategies or innovations. For sea level rise it may be high-end, for water management operations it is very much business as usual and conservative. Methods deployed are those of today. The sketch highlights the displaced morphodynamic environments in the former lowlands and the caped coast to which the shrunk country retreated. Natural processes shifting mud and sand will interact with submerged low land topography, after giving up on Plan A.

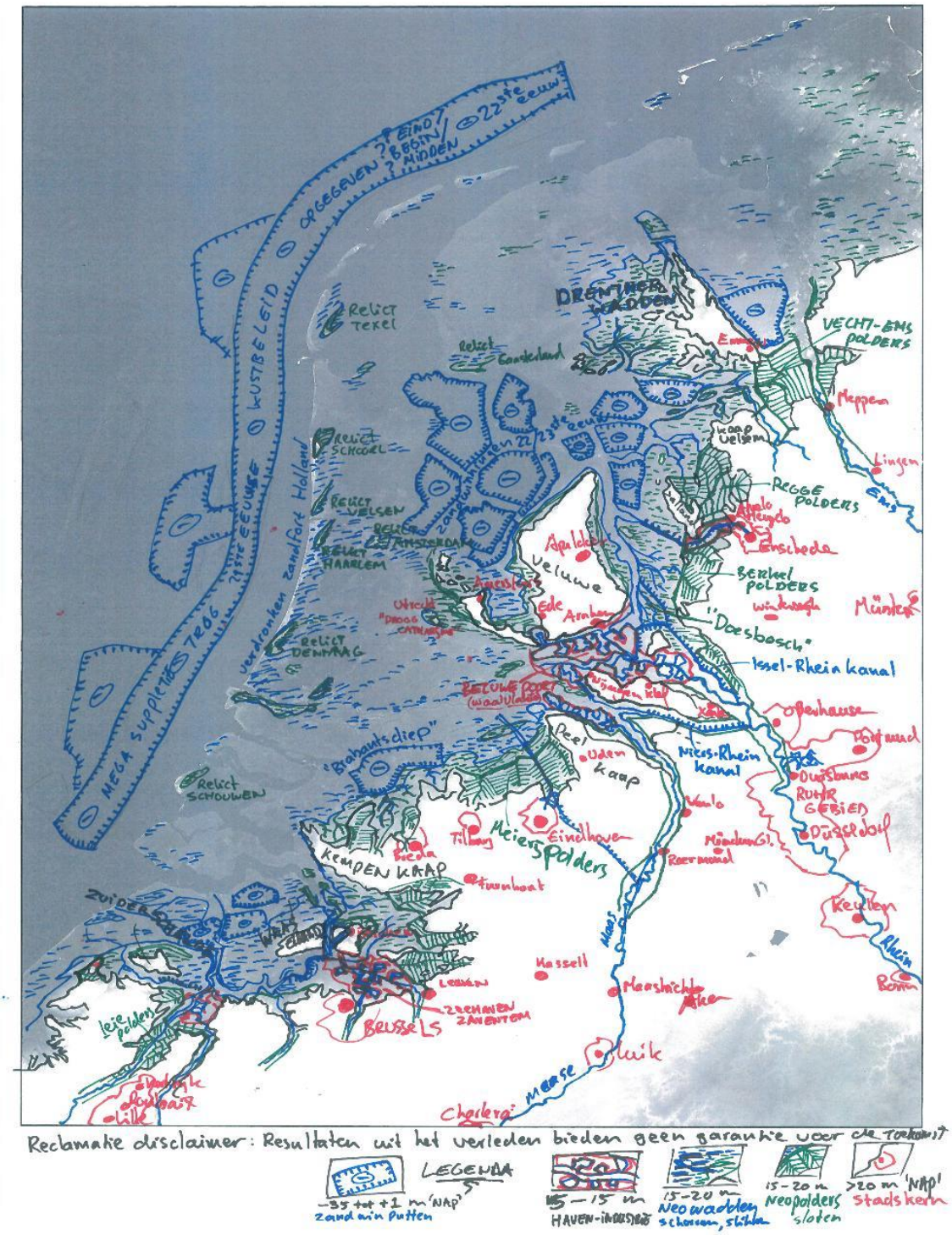


Figure D1 - Sketch map for the Low Countries in 2300 under extreme sea level rise (>> 5m) when retreat has become inevitable and 21st century defences are given up (VN.NL / Cohen 2019).

In 2300, Wadden shoals and salt marshes still exist in Drenthe and Flanders. There are still barrier islands, because that is what the Holland coast disintegrated into. In gloomy colours, the sketch shows heritage of the given-up Plan A, besides features of a Plan B executed starting halfway the 22nd century. From 21st-century Building with Nature strategies great deep dredging pits, reside in the former offshore. This may have been in vain in terms of fixating the old coastline, but is not totally

lost as nourishment effort: the Holland barrier island persevere on it as relicts. The dredging industry has survived and moved on too, still mining at optimal distances, now from the new coastline. Little has changed, also along rivers inland. Dikes are still built and neo-polders created, now in Brabant. A freshwater-tidal zone in the mouth of the Rhine persists, relocated 100+ km inland. That area also continues to be the gateway to the continental interior. Two out of three Rhine branches are new canals: the delta now begins in Oberhausen (Germany). One may also discover a somewhat cynical disclaimer and reclamation-historical references.

The sketch used an extreme new coast line around 15 m higher than 20th century sea level, also to stay out of any debate of what low-end or middle scenario would still be Plan-A defendable. For Flanders and Drenthe a few meters less would change the neogeography a lot (Figure D2) but for the Dutch coastal plain and Rhine delta, putting it at +5 or +10 meters does not change the scale of impact or complexity of moving to Plan B that much.

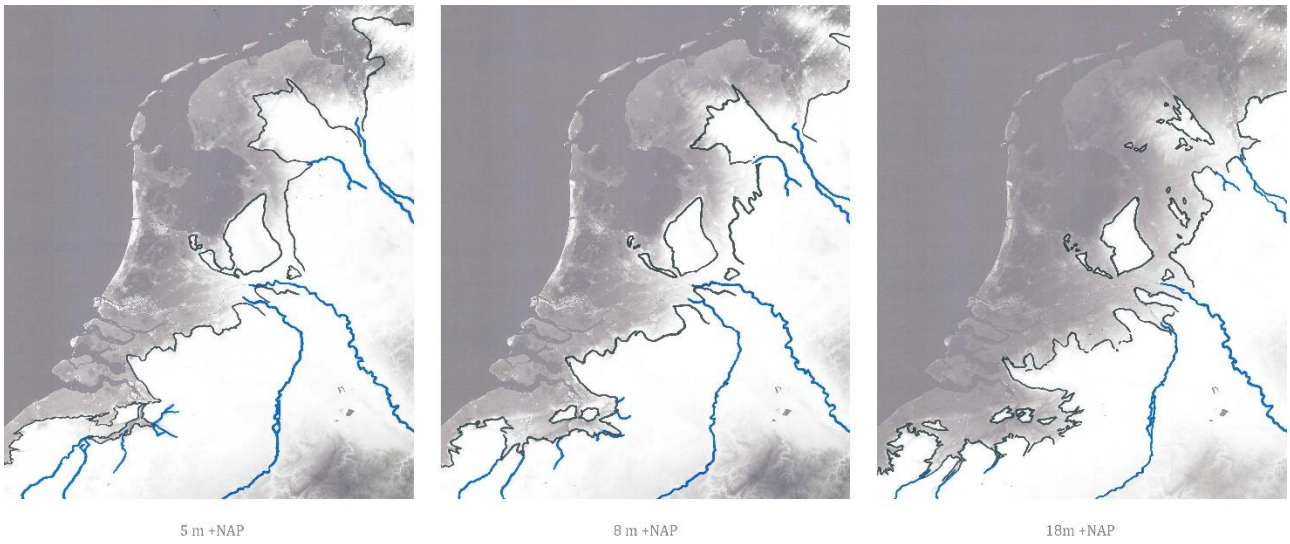


Figure D2 - Neogeography of the Low Countries: comparative impact of a SLR of +5, +8 and +18 meters.

E. Dutch Drowned Delta: opportunities of sea-level rise

Philip Minderhoud, Jasper Leuven, Kari-Anne Gerritsen | UU Water, Climate & Future Deltas hub

The drowning of a delta is seen as a threat. Current projections or 'pathways' into the future are aimed to 'sustain' the present way and traditions how we live and prosper in our delta. A future state of drowning, when sea water is no longer kept at bay following extreme sea level rise, is seen as a catastrophe and a failure to 'sustain'. For this reason, projections typically do not go beyond this horizon (Figure E1). This distant but inevitable future of a drowned Dutch delta presents a blind spot and a failed end-state. It may also be the start, however, of a new state that could offer unforeseen opportunities.

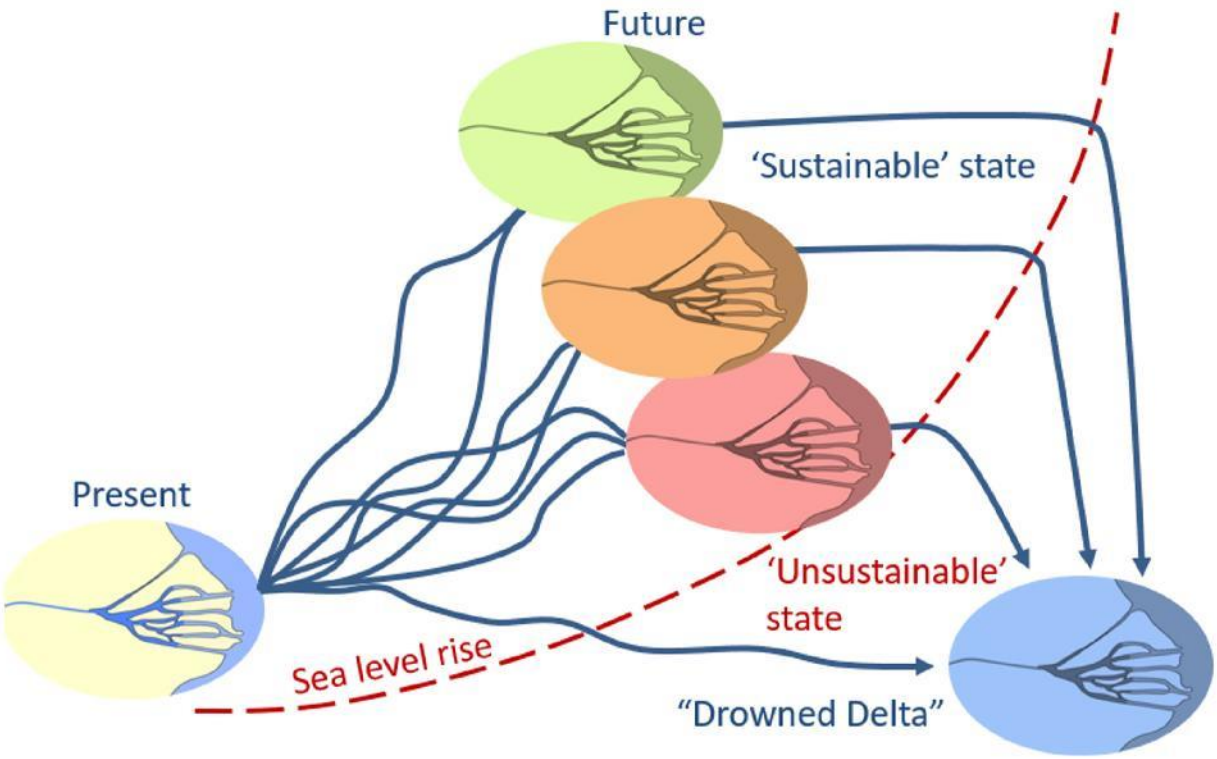


Figure E1 - Pathways towards a drowned delta. Under extreme sea level rise scenarios, all pathways end inevitably at some point in a drowned delta.

This line-of-thought lead to the creation of the Drowned Deltas project within the 'Pathways to Sustainability' 'Water, Climate & Future Deltas' hub at Utrecht University. Rather than presenting detailed designs of a future Dutch drowned delta, the sketch maps were created to facilitate the thought process during a dedicated workshop: "The opportunities of sea-level rise for a Drowned Dutch Delta" held in Nov 2019 (Figure E2). The workshop brought together professionals from NGO's, waterboards, engineering and consultancy companies, the ministry, research institutes and universities. The aim was to think outside the box of our traditional views, to discuss and discover the opportunities for the future drowned Dutch delta, and to define knowledge gaps and key research questions.

The workshop participants jumped into a far future in which the Dutch delta is no longer protected from rising sea water, low-lying areas are submerged by water and in open connection with the sea. The participants were supplied with inputs on expected biophysical and morphological dynamics conditions in the drowned state, such as water depth, flow velocity and tidal amplitude and were tasked to envision the ideal distribution of ecosystems and ecosystem services (i.e. opportunities) under these conditions. Next, the participants identified knowledge gaps that currently hampered their ability to identification, locate future opportunities, and created key research questions to address these gaps. The new research questions mainly covered three topics of the drowned delta: future biophysical conditions, environmental pollution and governance.
The maps (Figure E2) present idealized futures in which identified opportunities under a future Dutch drowned delta are optimally exploited and the submerged areas supply beneficial ecosystem services.

The insights the maps and the thought-experiment provide can be used to back cast and feed into present delta management decision-making. As it is likely that present and near-future decisions on how we manage our delta will impact the potential for future opportunities to prosper under drowned conditions (e.g. the impact of soil pollution on water quality). By learning from the future drowned delta and addressing key knowledge questions on how this future may look like, it may be able to ensure that when our delta drowns, it will, at least, drown on our own terms to optimize future conditions. In this way drowning is not the end, but the start of something new and beneficial, perhaps even in a way we cannot envision now.

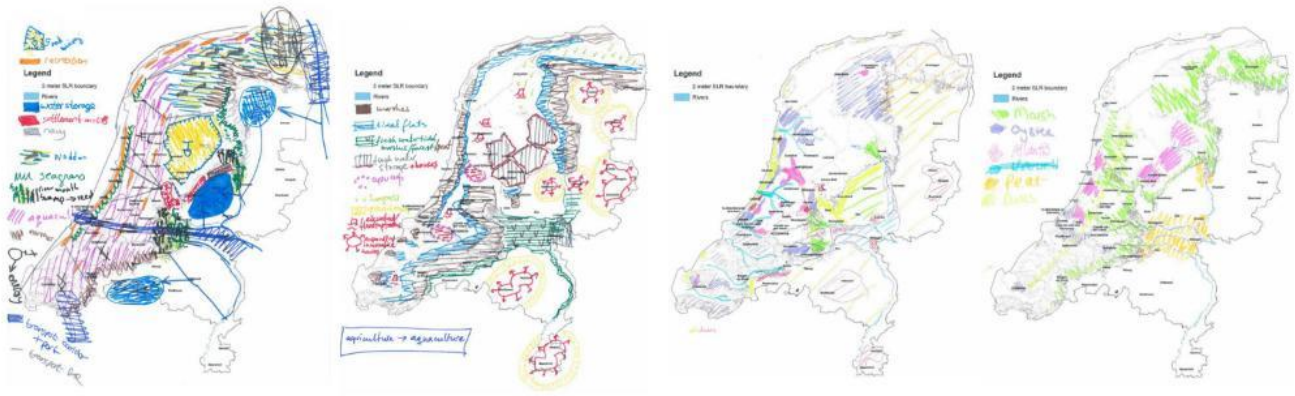


Figure E2 - Maps from the Drowned Deltas workshop showing optimal ecosystem and ecosystem services distribution for a future Dutch drowned delta

F. NL2120 A nature-based future for The Netherlands

Michael van Buuren | Wageningen University and Research

Introduction

Hundred years from now, the Netherlands will be a land of green cities, circular agriculture, and more forests, water and swamps (Baptist et al., 2020). A climate-proof Netherlands of this description is not just desirable but also feasible. The Netherlands faces serious challenges. Our country is becoming less habitable due to falling biodiversity, rising sea levels, land becoming salinized or drying out, an energy problem, floods, a housing shortage, soil and plagues of insects. If we do not do anything, these problems will only get worse. A new approach is necessary to exploit natural resources and to spatial planning to make a transition to a better, greener version of the Netherlands. A team of Wageningen researchers worked on a future vision for 2120 in which the forces of nature keep the Netherlands safe and prosperous (Baptist et al., 2019).

The map of the Netherlands in 2120, presented in figure F1, shows an expression of how the Netherlands might look like when the vision is applied. It is based on a number of criteria applying knowledge of fundamental natural systems and processes. For example, it had to deliver an optimal outcome for biodiversity, because only then the country can fundamentally thrive. Another starting point is to find and apply so-called ‘nature-based solutions’ for solving important environmental

problems as water safety and climate adaptation. The map represents one, ideal picture based on the criteria, but it is definitely not an utopia. It is weighed up what was probable, what was possible and what was desirable. The result is a picture of what is possible, to stimulate a discussion from a positive perspective on the future development of the country. The figure shows a comparison is made between the actual map of the Netherlands and the map belonging to the vision for 2120. Though major changes are proposed, the major shape and uses of the Netherlands are still visible.

To be able to fully apply nature based solutions, fundamental natural systems and processes have to be restored. After restoration, these systems and processes will enable sustainable use to provide society with protection, food, clean drinking water and agreeable places to live, work and recreate. For this, we combined the following five guiding principles:

The natural system as the starting point – The type of soil, the differences in elevation and the water systems in the Netherlands will determine the future of spatial planning and development. The natural system is the starting point for the solutions that we propose for a climate-proof and biologically diverse country.

Optimal use of water - To enhance biodiversity and quality of the natural environment and to use every drop of water optimally, our water management focuses on maximum retention, utilisation and water storage, with waste water disposal as the last resort.

Nature-inclusive society
We will take nature into account with all choices regarding energy, agriculture, circular economy, quality of life, urbanisation and water management. We look at the consequences of human actions for nature, protect ‘old nature’ more strictly and focus on natural processes, possibly in combination with technological solutions. We envision room for the emergence of new nature, making optimal use of human benefits (ecosystem services) and working on ecological connections that help flora and fauna to shift their distribution.

Circular economy
A more natural future for the Netherlands is based on the assumption that in 100 years the country will not only be climate neutral, but even climate positive, which means that we want to sequest more greenhouse gasses than we emit. This requires a transition towards a circular economy centred on sustainability, with a focus on services and a highly evolved, circular agricultural sector. At sea as well (aquaculture).

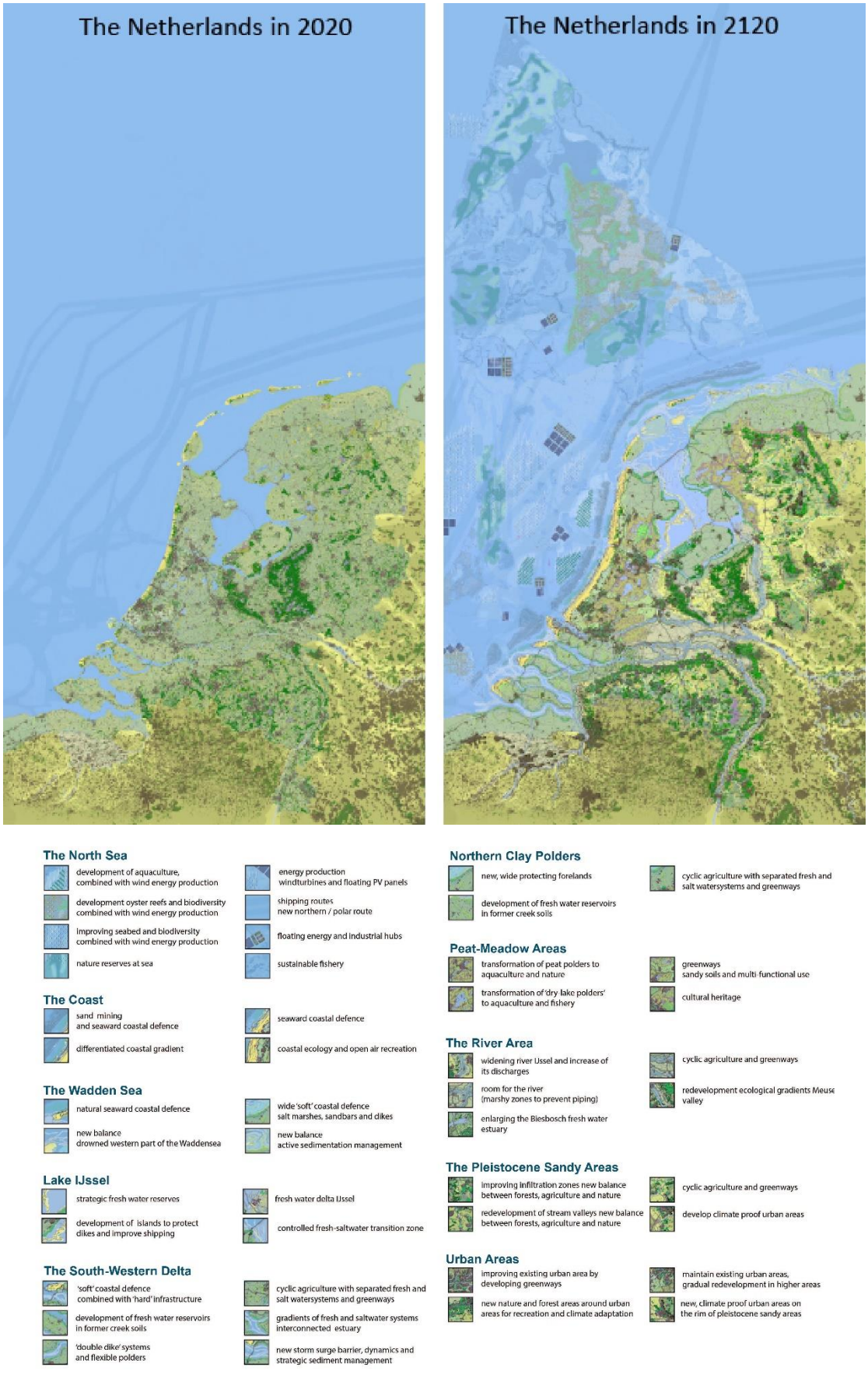


Figure F1 - The map of the Netherlands from the project "NL 2120; a nature-based future for the Netherlands" (Baptist et al., 2020). Existing situation (left) and proposed situation (right).

Adaptive spatial planning

The required adaptations to the effects of climate change, the energy transition, further urbanisation and increasing mobility lead to major changes in the environment and biodiversity. To ensure a safe, liveable, prosperous and sustainable future, the Netherlands must adapt to nature intelligently and make optimum use of natural processes in spatial planning. Examples of solutions include the 'Building with Nature' approach to flood risk management.

The major changes these principles imply are depicted in diagrams that show - for different Dutch landscape types - the most important changes that are used to draw the 'green map' of the Netherlands. Figure F2 shows examples of two of those landscape types: the river areas and the North Sea.

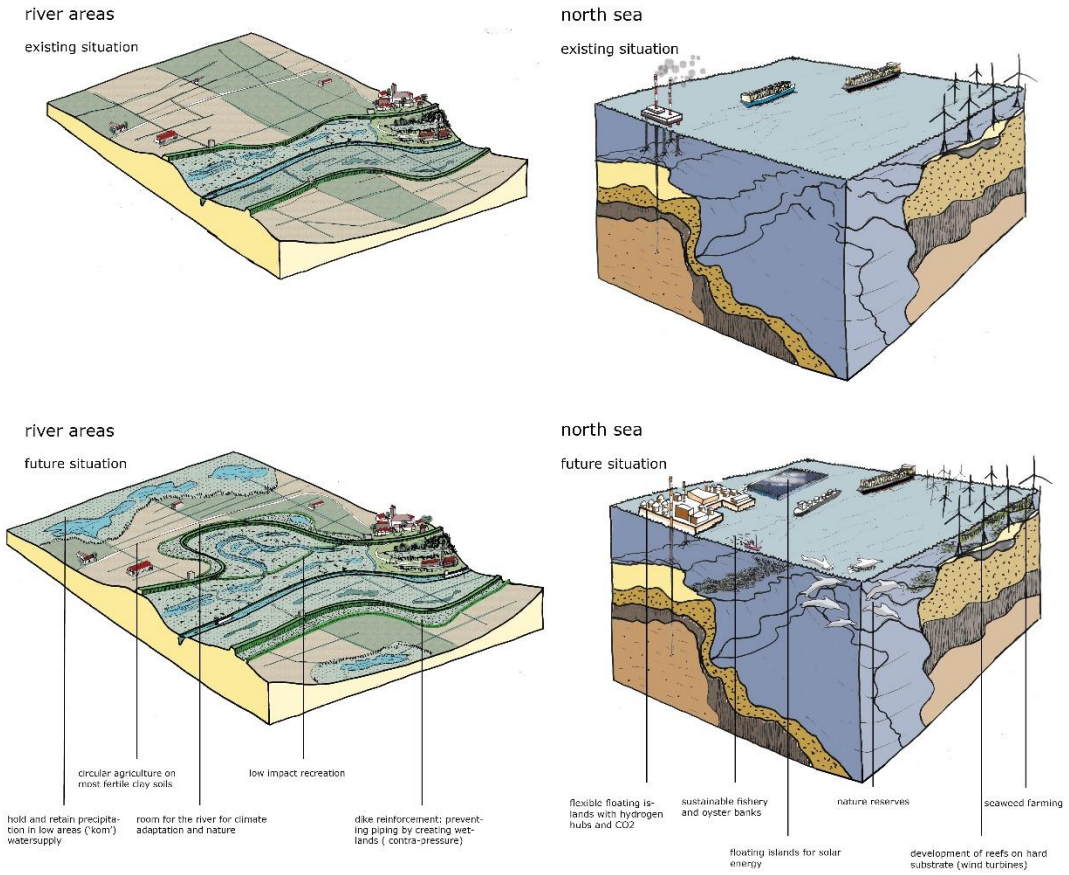


Figure F2 - Schemes representing the existing and the proposed zoning and lay-out of land use, restoring and or respecting natural systems in the landscape types 'river areas' and 'North Sea' in the Netherlands.

In our study ‘the Netherlands in 2120’, it was deliberately chosen not to develop a systematic range of scenarios, describing alternative options for the future. Many studies following this method have already been conducted. In this case, the major goal of the project is to express the consequences of clear and straightforward choices based on fundamental natural systems to evoke a thorough discussion on future and functional biodiversity. The starting points and basic criteria are set and from these, a positive perspective for the future of the Netherlands was drawn up. Existing and new knowledge from different experts from the Wageningen Research institutes, be it predominantly from a qualitative nature, is applied and combined in the project. It is not “a plan”; it is our contribution to the ongoing debate on the future of the Dutch Delta.

Some results

So what could the Netherlands look like in 100 years’ time? On the map of the future, it looks as though the IJsselmeer has shrunk. It has gained a second shoreline on a chain of overlapping islands and sand banks parallel to the existing lakeshore. We propose to keep the Afsluitdijk. That way, the IJsselmeer will remain the largest freshwater reservoir in North-west Europe. Another proposal is to discharge the peaks of the Rhine River that arise through climate change via the IJssel. At present most of the water is channelled into the Waal. The low areas along the Waal are however densely populated, whereas the IJssel is surrounded by higher elevated areas. Widening the IJssel would create more space for biodiversity.

The Netherlands was originally a wetland, a delta with water birds, swamps and wet forests. It is nice that the wolf is settling here, but it would be even nicer if the Dalmatian pelican that was living in the Netherlands in Roman times made a comeback. The Dalmatian pelican could come back if there were more wetlands and higher temperatures.

In our vision, ‘moving’ (abandoning) the towns and lands on the lower parts of the Netherlands, is not going to happen within the time-frame of the next hundred years. What is expected to happen is to green existing cities with vertical gardens, green roofs and more trees. It will also be necessary to build a lot of new housing in safer places, e.g. around the Veluwe and in Brabant. Agriculture will be transformed to circular production, both on land and sea. Less land will be used for agriculture due to higher productivity, to nature’s advantage. The cultivation of seaweed, lobster and shellfish will also be more established in the Netherlands. The bases of wind turbines become structures for farming oysters or provide anchor points for seaweed farming. Fs for the energy supply, offshore wind farms will be combined with solar panels and hydrogen plants on floating islands that become hubs for logistic and hydrogen based heavy industry.

G. Delta Plan X

Elma van Boxel, Kristian Koreman and Negar Sanaan Bensi | ZUS
Joep Storms, Geert van der Meulen, Ranee Leung and Jos Timmermans | TU Delft.

Delta plan X [G] presents a workflow to prepare for adaptation. The plan aims to address the challenges stemming from sea level rise and climate change in concert with continued socio-economic change. The workflow prepares the tools for an analytic and engineering approach that evaluates upcoming transformative designs on societal, engineering, geographical, economic and policy principles. The workflow does not offer an implementation strategy but includes stakeholder interaction and real world and numerical experiments as test sites.

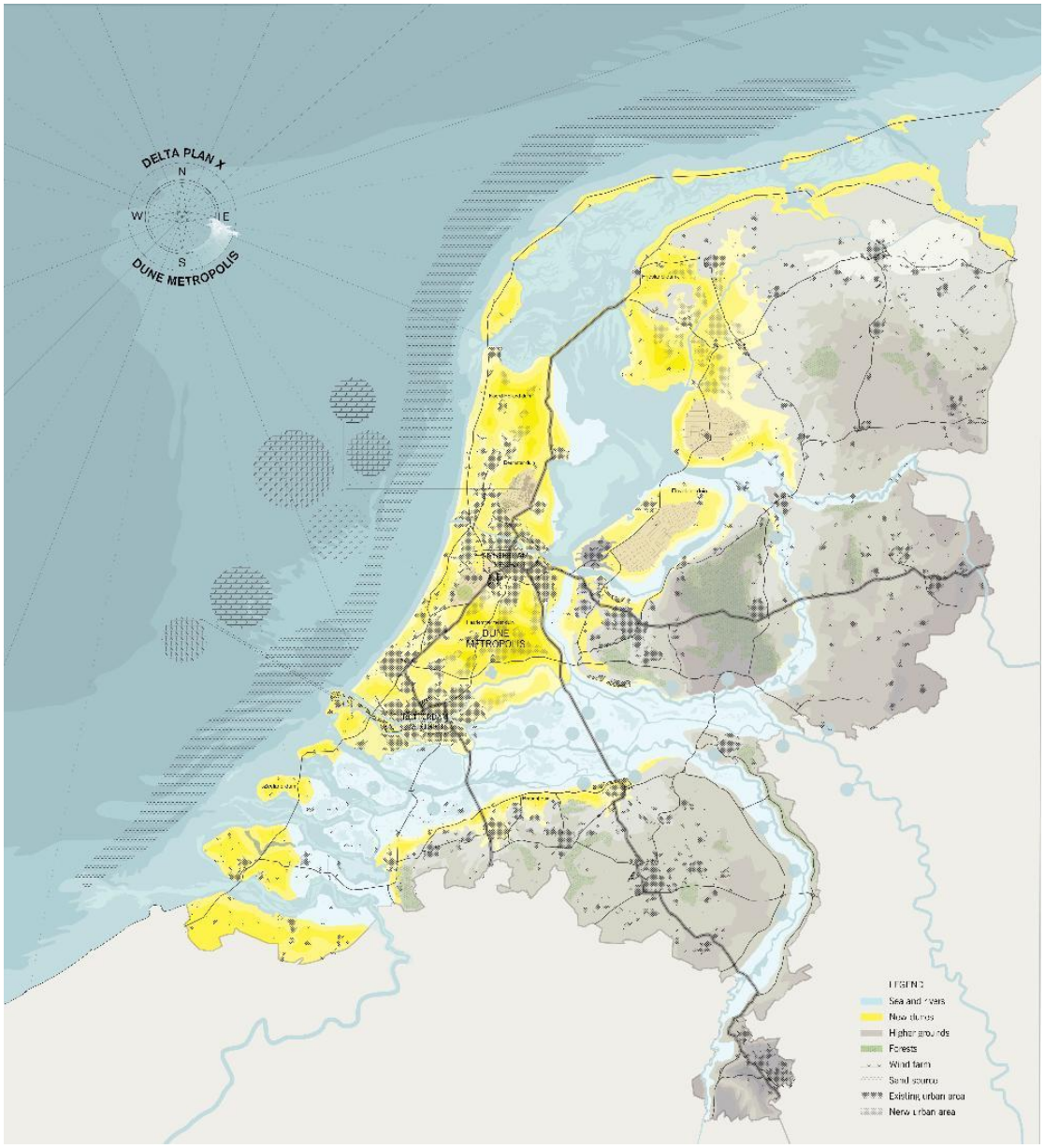


Figure G1 - Delta Plan X possible outcome

Why

An accelerated sea level rise introduces new challenges to the Netherlands. Building on past and existing expertise and innovations, our country will remain safe for a moderate rise of the sea level in the decades to come. However, current IPCC reports indicate that sea level will rise beyond the year 2100 and may exceed +3m, surpassing our current coastal defence infrastructure.

The fact that we know neither the maximum future sea level, nor when it will be reached does not excuse us from undertaking serious efforts to assess and mitigate the impact of the long-term sea level rise on the future development of the Netherlands.

It is expected that the costs of climate change mitigation measures (flood protection, impact of salinization, drought, etc.) will rise significantly in the future. In addition, additional costs are to be expected for infrastructure, health, agriculture, etc. To accommodate and prepare for these rising costs it is of crucial importance to have a national strategy and financially evaluate each plausible plan that will allow us to ensure the existence of the Netherlands.

Developing a strategy to cope with sea level rise beyond 2100 is highly complex yet urgent and goes beyond any single discipline and expertise. Given the inherent uncertainty of future climate change, sea level, socio-economic trends and governmental development, this project aims to deliver a strategy consisting of methods and tools rather than a single 'solution'.

Strategies for 2300 and beyond should assume that not only the climate but also the Netherlands will change significantly. What will be the population (Figure G2)? How will they earn their income and how flourishing will our economy be? How will the future agriculture and infrastructure develop? Where will the energy come from? We also need to define the main climate induced natural, economic and ecologic stresses that will affect our country. Where will they occur and how that affects our urban, rural and economic areas (Figure G3).

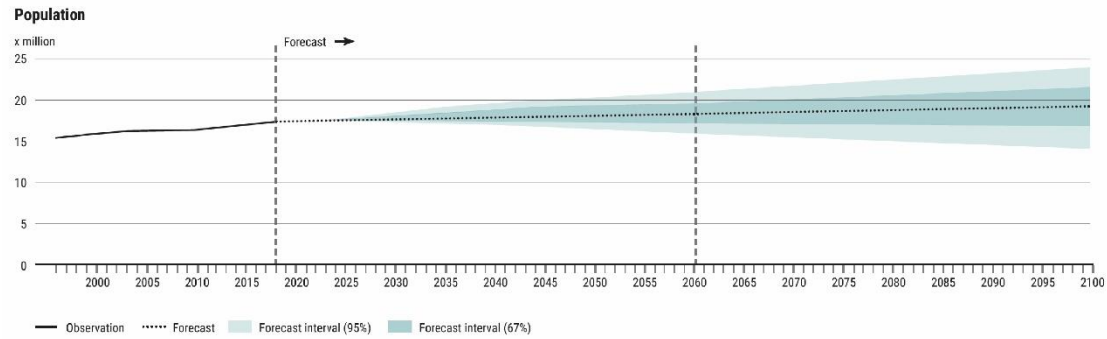


Figure G2 - Population forecast towards 2100 from CBS forcast 2020-2060 (Source, Statistics Netherlands (CBS)

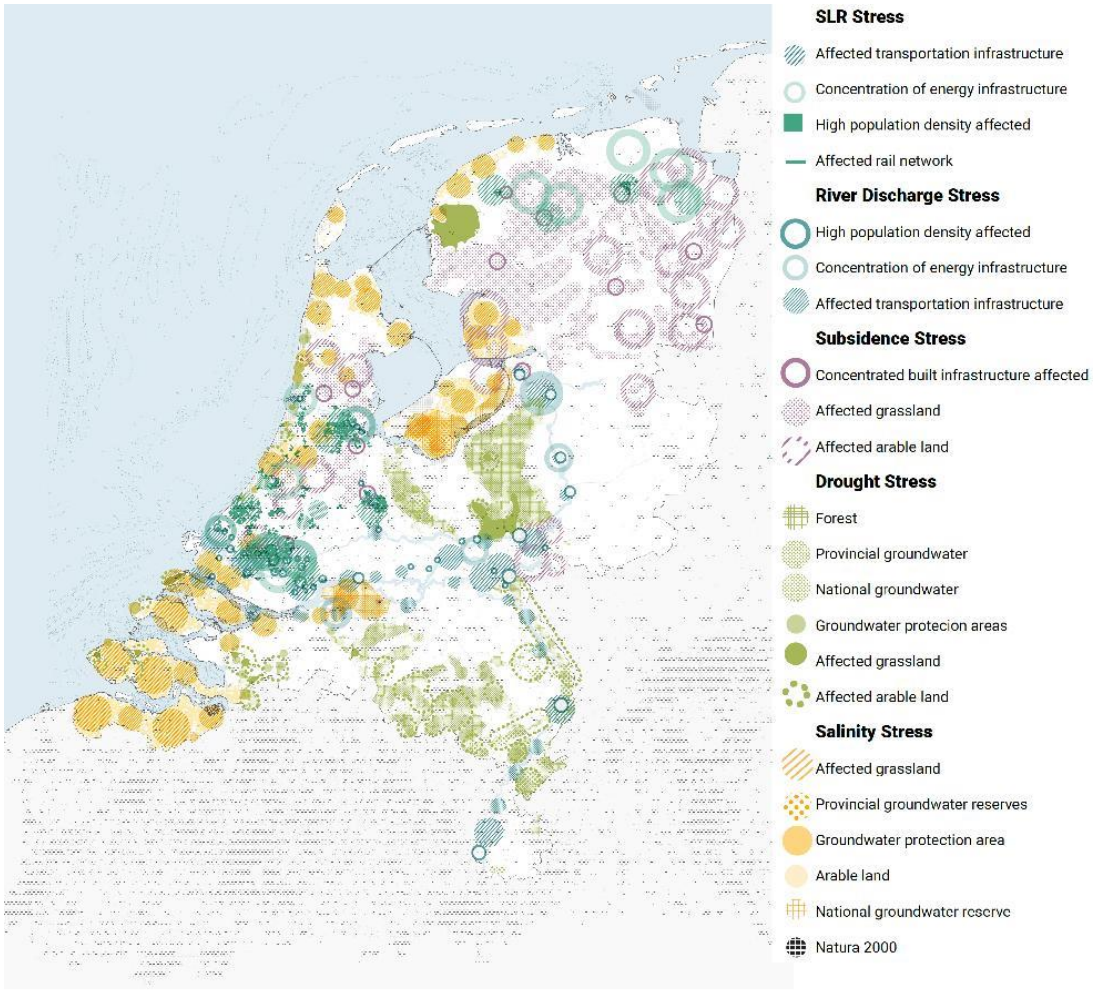


Figure G3 - Compiled map of identified current climate-related pressures in the Netherlands.

How

Landscape and urban designers have created multiple new and innovative designs for our future Dutch society under a growing threat of flooding. However, to utilise such transformative designs, they should be holistic, based on and tested against realistic societal, engineering, geographical, economic and policy principles. Such an approach is currently absent. This means ensuring an integrated design approach involving all relevant disciplines in an early stage of the design.

Delta Plan X is an immersive and collaborative initiation for thinking, testing, computing, predicting, and visualizing the future of the Netherlands within the context of climate crisis and sea level rise. The vision aims to get engaged with the multiplicity of issues affecting the future of the planning; thinking about them not merely as threats, rather a new context and potential opportunities to (re) form the Netherlands.

Given the uncertainty in sea level beyond 2100 with a sea level exceeding +3m above present-day sea level, the aims of this proposal are twofold: 1. Develop and implement a workflow that will allow for realistic and feasible Dutch landscape designs that can be objectively assessed, involving the expertise of academia, knowledge institutes, design practices, the practical experience of (local) governments

and municipalities and market parties and 2. Implement the optimal current engineering practice that aligns both the short term (< 2100) and long term (> 2100) needs, thus combining present-day practices with future design visions.

Therefore, on one hand, Delta Plan X imbues a new momentum into 'the making of the Netherlands'. From long term and pan- European perspectives, new contours for the Netherlands will be conceived and planned. On the other hand, Delta Plan X projects this large-scale vision locally on specific test sites. In doing so, it positions the local specific sites in the broader contexts of the European landscape and global climate change.

Figure G4 shows our anticipated workflow that allows for a collaboration amongst different disciplines and expertise. Based on a set of constraints, initial visions are produced and then tested using a set of indicators. After assuring the feasibility of the initial vision, the process continues with 'test sites' as actual prototypes where the design can be tested by means of experimental or numerical simulations for the safety, socio-economic, ecologic and infrastructural impact. Learning from the test sites will feed back into the initial designs. Given the inherent uncertainty in our national constraints at 2300, a feasibility tool as proposed here will help to assess our future design and engineering challenges through an iterative, inclusive and flexible process.

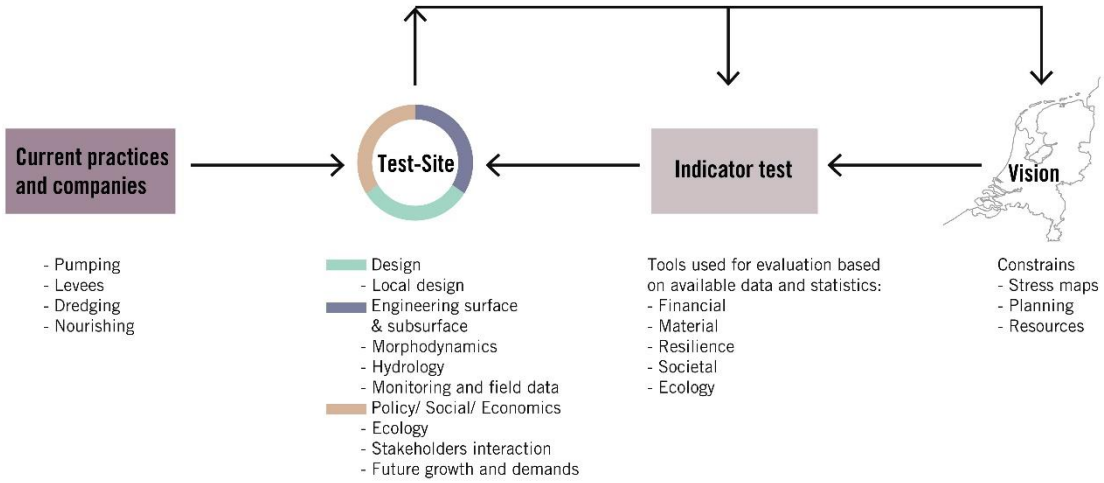


Figure G4 - Workflow

3. Comparative reflection

The IPCC distinguishes in its resent SROCC report four responses to sea level rise: protect, accommodate, advance, and retreat, that can be realized through engineering, sediment based and ecosystem based approaches (H.O. Pörtner, 2019). Although the seven plans and designs considered in this reflection differ widely in their objectives, guiding principles, and implementation approaches, they can be mapped on the four IPCC SROCC response types. A Netherlands protected from the sea, accommodating the sea, advanced into the sea, and retreated from the sea. Engineering, sediment and ecosystem bases approaches can be part of all these responses.

Scenarios used

The sea level rise scenarios used as starting point are a first and very relevant factor in comparing the seven plans included. Some plans and designs use clear sea level rise ranges, others aim to avoid the discussion by using extreme values and remove flood defences to make sure that protection, advance and to a large extend accommodate strategies are out of reach. Below we summarize the sea level rise scenarios to make them accessible to the reader as background information.

#	Plan or design	Short	SLR (m)	period
A	Plan B NL2200	Plan B NL2200	6	2200
B	New Netherlands	New Netherlands	2-10	centuries
C	Mapping the solution space to high sea level rise for NL	SLR Solutions	2-4	-
D	The Low Countries in 2300 under extreme sea-level rise	VN Plan B	>2 >>5	2150 2300
E	Identifying opportunities for the drowned Dutch delta	Drowned Delta	>2 (no flood defences)	2100-2200
F	NL2120 A nature-based future for The Netherlands	NL Nature-based	1.5	2120
G	Delta Plan X	Delta Plan X	>3	2300

In short

Plan B NL2200 [A] is positioned on the retreat side of accommodate. It embarks on a shift of the coastline of the Netherlands to the east. A Netherlands without dikes, but with a protected multi-functional lagoon. To realize this protection it maintains the west coast as a barrier to the North Sea. It employs engineering approaches to connect functions and cities within the lagoon to each other and to the then main land. The main objective of the plan is however to paint a new future for the Netherlands. It emphasizes the need for alternative options. For the realisation of such a spatial vision, a revival of the Dutch national spatial planning tradition is deemed indispensable.

New Netherlands [B] retreats and protects. The Netherlands becomes a smaller country with a focus on the Randstad. This smaller country protects itself from extreme sea levels by a shortened coastline, intensive nourishments and pumps. These flood protection strategies are capable of protecting it to up

to sea level rise of 10 m. The relocating of 1.7 million inhabitants reinforces current population trends and will raise resistance. It continues the Dutch history in flood protection, and preserves its cultural and heritage values. New Netherlands continues the historic narrative of the Netherlands and their sea.

The study on the solution space to high sea level rise Solutions [C] translates the advance, protect and accommodate, retreat of the IPCC strategies to the Netherlands. The study aims to describe four corners of the solution space: protect the entire country with an advance, open or closed protective strategy or accommodates salt water in low-lying regions of the country. The strategies employ diverse rates of hard or soft measures, sand nourishment and wetlands, islands, elevated or floating buildings, salt and/or flood tolerant crops, raising land, spatial planning and inland migration, and are evaluated with regard to their societal and technical feasibility and robustness. Strategies are concatenated into possible high-level pathways describing key decisions that could enable or trigger moving to one of the solutions and could inform an adaptive plan. The study follows a policy analytic approach in which developments are linked with the solutions required to solve the problem.

VN Plan B [D] sketches a renewed transgressive episode for the North Sea which a consequential retreat of the socio-economic part of the delta system. The sketch highlights the displaced morpho-dynamic environments in the former lowlands and the caped coast to which the shrunk country retreated. Natural processes shifting mud and sand interact with the submerged post Plan A land topography. The delta begins in Oberhausen and the Rhine is still the gateway to Europe. The retreated socio-economic system conserves current water management's practice because it builds dikes and neo-polders in Brabant. Apart from the relics of advance, protect and accommodate strategies that have failed to preserve the old country, the Netherlands looks like a remake of the current country on a higher elevation. VN Plan B continues the geomorphological development of our lowlands and repeats its socio-economic narrative on higher grounds.

Drowned Delta [E] jumps into the distant but inevitable future of our delta. It is an advance from the full socio-economic retreat option. Plan development starts from future biophysical and morpho-dynamic conditions, operationalized in future water depths, flow velocities and tidal ranges. It then proceeds to develop opportunities for the drowned delta. The resulting plans employs nature based solutions, floating residential areas and port and corridor infrastructures. It identifies governance as a knowledge gap and points at the environmental consequences of drowning. Drowned Delta continues the geomorphological development of our lowlands and innovates its socio-economic system.

NL 2120 Nature-based [F] develops an integrated accommodate vision for the Netherlands. The design is driven by the climate, biodiversity, housing, energy, agricultural, water, and delta management challenges that confront the Netherlands. It unravels their underlying causes and reverses them by developing a better and greener version of the Netherlands by consistently applying and valuing natural system processes. The physical implementation is worked out in conceptual designs that thoroughly analyse and explain the natural processes underlying their future functioning. The result is a vision, a

contribution to the discussion that leaves democracy and politicians to decide. NL 2120 Nature-based exploits natural processes to develop a better and greener Netherlands.

Delta plan X [G] presents a workflow to prepare for adaptation. The plan aims to address the challenges stemming from sea level rise and climate change in concert with continued socio-economic change. The workflow prepares the tools for an analytic and engineering approach that evaluates upcoming transformative designs on societal, engineering, geographical, economic and policy principles. The workflow does not offer an implementation strategy but includes stakeholder interaction and real world and numerical experiments as test sites. Delta plan X proposes an engineering approach to transformative spatial design.

Guiding principles

We distinguish three guiding principles that together determine the outcome of the plans and designs: method, outcome and implementation. Method addresses the approach to development. How does the plan orient itself towards history and future? Does it use an analytic or a design approach? The second guiding principle is related to the plan outcome: which regions does it focus on? What are the implicit or explicit values that guide design decisions? These guiding principles expose underlying values that are difficult to agree on and will distort the adaptation discussion to come. They are however not static and their diversity is required to create the requisite variety (Ashby, 1991) needed to approach the complex challenges ahead. Thirdly, we compare the implementation strategies that the plans propose for their realization. In the following, we address these three guiding principles in plan development.

Plan development

Most of the contributions included in this article are design oriented. They create a new future for the Netherlands and treat higher sea levels as a boundary condition. These plans emphasize the opportunities: retreat is not a defeat. SLR Solutions [C], and to a lesser extent New Netherlands [B], are exceptions. SLR Solutions [C] starts from the problems resulting from extreme sea level rise, and identified and assessed plausible solutions. This study considers retreat as a long-term option following upon accommodation measures.

New Netherlands [B] is a design but problem oriented. It defines discontinuation of the Dutch history as the problem and evaluates partial retreat as a feasible strategy to continue the Dutch national narrative. Delta Plan X proposes a similar analytic approach towards design in order to create a new feasible alternative for the Dutch territory. These three plans use an analytic approach to problem solving or design. VN Plan B [D] and Drowned Delta [E] start from retreat. They redevelop or redesign the country starting from a changed geography, with inherited physical substrate and retained morpho-dynamical functioning. NL 2120 Nature-based [F] is oriented towards the future. It is a design. This design is not problem oriented but driven by a vision on the future. A future in which many challenges of the Netherlands will be solved. NL 2120 Nature-based is analytic, but not engineering: it analyses the functioning of landscape units at a conceptual level.

Plan outcomes

Not all the plans and designs emphasize their outcome. Plan B NL2200 [A] emphasizes the importance of spatial planning at the national level. Delta Plan X [G] similarly focusses on a workflow that translates the countries "programme" in terms of housing, economy, mobility, energy, etc., and proposes a design approach that is supported by analyses and engineering. VN Plan B [D], Drowned Delta [E] and to a large extent NL2120 Nature-based [F] are strongly influenced by new geomorphological realities in distant futures. NL2120 Nature-based [F] does so for 2120 and includes ecology. These designs start from the substratum (van Schaick & Klaasen, 2011), or "ondergrond", in the Dutch layer approach to spatial planning. The term substrate in this context includes both the inherited 'passive' substrate as well as the dynamics of the substrate –for example the hydrological system-, and the dynamic surface to subsurface interaction –the morpho-dynamics system. These plans do not only take the shrunk land area of the country as a boundary condition but also its altered physical functioning.

VN Plan B [D] then repeats Dutch land reclamation history shifted inland, while Drowned Delta [E] focuses on continued use of the drowned area. Drowned Delta [E] and NL2120 Nature-based [F] are the only designs that include urban development on the higher grounds. These plans turn the time scales of the layer approach around: the substratum changes fast and the network and occupation layers follow. To the opposite, New Netherlands [B] conserves (part of) the current base layer to facilitate the historic continuity of developments in the network and occupation layers. Where VN Plan B [D] and Drowned Delta [E] emphasize the morphological functioning of the substratum, coast and rivers, NL2120 Nature-based [F] takes a wider range of ecological and landscape processes in managed wetland and uplands into account. This vision, however, designs for a less extreme and shorter-term future and uses these processes as operational principles that have an intrinsic capacity to solve challenges (they are not boundary conditions).

Implementation strategy

The majority of the plans considered in this paper discuss an implementation strategy for their plan. The strategies range from strong coordination by the national government (Plan B NL2200 [A]) to transition management approaches (New Netherlands [B]). The study on the solution space and potential adaptation pathways (SLR Solution [C]) recognizes the need for transformative change on the long term. The study acknowledges that autonomous changes occur and that a transformative change requires collective action and could be enabled through small steps and quick-wins. Furthermore, the study recognizes the importance of connecting to transitions in other domains and the need to secure the adaptation vision in an agreement, law, fund, or commission or an institution like the Delta Program. Being a study on solution space, it describes alternative pathways and strategic decisions and developments that would foreclose or open potential outcomes. Delta Plan X [G] aims to deliver a substantiated strategy including methods and tools rather than a single 'solution'. It

includes socio-economic and governmental development as an uncertain factor and stakeholder interaction as a method. Is does not include the implementation of their workflow.
In the policy sciences in general, two lines of thought can be distinguished on how policy changes society. Incrementalism (Lindblom, 1959) analyses policy change as a sequence of smaller adaptations of existing policies and is usually connected to incremental change and muddling through. The agenda setting literature (Jones & Baumgartner, 2004; Kingdon & Thurber, 1984) explains transformative policy change by analysing how policy entrepreneurs and advocacy coalitions manage to move issues onto the political agenda. Both theories are descriptive rather than prescriptive. Transition Management (Loorbach, 2010) similarly addresses transformative change, but is action -management- oriented, prescriptive, and normative in its acceptance of sustainability. It evaluates the role of existing institutions (the regime) as hampering transformative change.
Although most plans and designs recognize the transformative character of adaptation to high-end sea level rise, their implementation strategies are not always in line with policy theory. Plan B NL2200 [A] proposes stronger steering at the national level to implement coordinated transformative change. NL 2120 Nature-based [F] similarly points at the role of politicians to make the final trade-offs. The vision is transformative in stimulating the societal and political discussion on a clear perspective to cope with the great challenges in an integrated way. It does not yet contain a clear strategy, but calls for a broad debate on the most relevant or desirable strategy. SLR Solutions [C] proposes a transformative strategy that balances government and governance. New Netherlands [B] is consistent with policy theory. It embraces transition management as its approach and presents its design as part of the transition management process. The table below summarises the methods, outcome and implementation strategies for the seven plans as described above.

#	Plan/Design	Method	Outcome	Implementation
A	Plan B NL2200	vision→substrate→analysis←→design	Protected lagoon	National coordination
B	New Netherlands	problem→design→engineering	Core country	Transition management
C	SLR Solutions	problem→analyses→engineering	Solution space	Conducted transformation
D	VN Plan B	substrate→development	Neo-Netherlands	Unguided
E	Drowned Delta	substrate→design	Functional drowned delta	Knowledge gap
F	NL2120 Nature-based	vision→substrate→analysis←→design	Green Netherlands	Democratic
G	Delta Plan X	analysis←→design←→engineering	Undetermined	Workflow

Accumulating the methods applied would result in a problem solving or design oriented approach. The design oriented approach starts from a substrate as proposed in Drowned Delta [E], VN Plan B [D] and NL2120 nature-based [F] and a socio-economic program as proposed in Delta Plan X [G]. The

problem solving approach starts from the problem, sea level rise, and would use the substrate as a constraint and socio-economic consequence as evaluation criteria:

Design:	analysis ←→ **design** ← →	engineering | substrate and socio-economic program (vision)
Problem solving:	analysis ←→ **solution** ← →	engineering problem

Retreat?

Although clearly distinguished as a response option by the IPCC, the word *retreat* is only used once in the plans and designs in this paper: in VN Plan B [D], only after alternative strategies became obsolete. At the same time, most plans take some serious retreat as a starting point. SLR Solutions [C] considers*retreat* as part of *accommodate*. The extent and degree of retreat, however, differ. Extent of retreat here refers to the amount of land that becomes sea and the degree refers to the functionalities that disappear. The first depends on the SLR scenarios for the plan and the land area that consequently floods. Except for New Netherlands [B], the extent of retreat for all plans depends on the sea level rise accommodated in the plan or design. The degree of retreat is in most plans far more limited: most plans sketch a retreat of some functions to the higher grounds. Most of the further design, however, focuses on the potential of the emerging wetlands and water bodies for fisheries, housing, recreation, and ecology; on protection of historic cities, towns and villages from flooding and on integrating all that into the future fabric of the Netherlands with connecting infrastructures.

In discussing retreat as a sea level rise response, the SLR Solutions [C] mapping of Deltares and the Delta Program is interesting. While it presents their four sea level rise response strategies as the "four corners of the solution space", the designs of New Netherlands [B] and VN Plan B [D] are not contained within the thus demarcated solution space. All plans also remain superficial and generic and describe retreat as shifting the coast to the east (Plan B NL2200 [A]), displacing morpho-dynamic environments (VN Plan B [D]) and drowning deltaic land (Drowned Delta [E]). However, SLR Solutions [C] includes inland migration in their accommodate solution and New Netherlands [B] estimates that 1.7 million inhabitants need to be relocated. Consequently, the focus on developments of the higher grounds are very limited. No Silicon Hills on the Veluwe or port industrial complexes between Arnhem and Nijmegen.

International perspective

The impact of a rising sea level is not limited to our national boundaries, and water crosses national boundaries (Fig. 3.1). VN Plan B [D] touches upon the morphodynamic and water management functional changes of the Rhine in Germany and Scheldt in Belgium. Plan B NL 2200 [A] also drowns the lower part of Belgium including the area around Antwerp. None of the plans and designs fully take up the challenge to Belgium and Germany. It seems relevant to raise the issue on how to align national plans, ambitions, safety and development in an early stage by engaging with international partners.

Figure 3.1 - Depiction of the chain of barrier islands with coastal dunes of the Netherlands and surroundings in Roman times. Back-barrier waters and coastal plain are left white, uplands black. Van Veen (1949)

Anthropocene versus Holocene barrier coasts

Reviewing all the plans, there seems consensus that as the Anthropocene unfolds, human actions will continue to grow as an ever more relevant geological force. A pristine Holocene coastal system, with its barrier islands and estuaries, with rivers that are completely free to meander, flood and deposit their sediments on floodplains, in an equilibrium with hardly rising sea levels for the past 4000 years or so, does not appear to return in the Netherlands of the future. The landscape and its waters stay a managed and designed system, while distribution of sediments over floodplains and channels will remain guided by engineering. But facing the Anthropocene, the coastline of the Netherlands finds itself subject to *Dolan's Dilemma*: barrier islands eventually become subject to risk of drowning in situ with rising sea levels if the rate of barrier retreat is inhibited due to artificial stabilization of the beach or dunes that impede overwash or tidal-inlet processes (Dolan, 1972).

4. What if?

Most of the spatial plans and designs described and discussed above start from some sort of manageable decision-making and implementation strategies that will result in the plan to be accepted, decided on and realized. Scenarios are used to deal with uncertain rates and ultimate levels of sea level rise, climate and/or socio-economic change. On the road to realization, new insights, knowledge and unexpected discourses might occur that re-direct developments and perspectives. These occurrences move around somewhere in the grey zone between unknown unknowns and known unknowns.

"It's the economy, stupid!"

The plans and designs discussed in this paper necessarily suppose some kind of managed adaptation. However, what if a seemingly continuous flow of ever more alarming results from science and monitoring, point at a more and more disastrous development? How will investors react? What if an attractive design inspires citizens to act? Will we then still have the strong economy required to pay for radical adaptation? Will we still be in control?

Untimely 1:10.001 event

With the new norms for flood protection, the probability of flooding of the southern part of the province of South Holland is 1:10.000 a year. How will the occurrence of a 1:10.001 storm surge event and the resulting flooding influence the adaptation process? Will we reclaim and rebuild that part of the Netherlands? Or will we then exchange a hitherto followed protect or advance strategy for accommodate or retreat?

Environmentally expensive

Drowned Delta [E] points at environmental issues in the inundated areas as a key knowledge question. Evaluating the feasibility of retreat may indeed be crucial to understand the processes and effects of pollutants currently present in the Dutch environment and to design a mitigation and financing strategy for their remediation before they drown. This environmental issue co-determines the feasibility of a managed retreat. Should we avoid retreat not for economic, cultural or historic reasons, but to protect the North Sea and the lagoon from pollution?

5. Final remarks

In this contribution, we discussed seven designs and plans for the Netherlands to adapt to high (multi-meter) sea level rise. We presented plans and designs from a diverse group of scholars and professionals. Notwithstanding their diverse background, the plans and designs do not cover the entire range of options. Most of them are extreme *accommodate* or minimal *retreat* strategies.
Advance options are only acknowledged by the SLR Solutions [C] analysis that aims to demarcate the solution space. The focus on *accommodate* and *retreat* is probably a sign of the times: it does currently not sound very logic to *advance* into the sea while it is rising. Furthermore, many *advance* related plans exist and featured prominently on the political agenda in terms of tulips and airports over the past decade, which makes them less interesting to explore.

While many plans address a retreat (or drowning), none of these plans attempted to analyse what the Dutch economy would look like in the event of abandonment or displacement of the Randstad. Retreat will be both expensive and a risk for the economy, because of economic decline and loss of economic value. In addition, a drowning Randstad will have unprecedented environmental impact. One would risk leaking chemicals from drowned building, factories, landfills, or other infrastructure for centuries to come and thus a need for remediation that adds to the cost of retreat. We might even be forced to include these costs in the risk assessments of *protection* strategies and increase investments in dikes and storm surge barriers. What are the fall back options we would have in case retreat is not an option?

The key conclusion of this comparative article is that diversity is essential in this stage of planning. All plans address future challenges from a very different starting point and yet address the same key challenge of the impact of sea level rise. We advise to further broaden the planning and design horizon perspective by including *advance* and full *retreat* options. These plans and designs should not only be developed individually but also analysed as a sequence of adaptation strategies in a pathway that is technically, morphologically, societally, politically and culturally desirable or acceptable and economically feasible. SLR Solutions [C] and Delta Plan X [G] give examples of this approach. Full managed retreat should be included in these pathways as the single robust final state. Besides managed retreat, we discussed possible autonomous slow or fast adaptation processes triggered by economic decline, a disaster or lack of trust.

While the outcome of the plans might still show a limited range, the diverse approaches need to be cherished. It is worthwhile to apply problem solving and design approaches. It is instructive to analyse future coastal, landscape, and ecological dynamics. It is worthwhile to explore visions on the Netherlands after adaptation and a contingent socio-economic program. We found some relevant knowledge gaps that extend the research agenda. The cost of adaptation (*protect, accommodate, advance*, and *retreat*), societal implications and its environmental impact need to be analysed. We need tools and models, able to explore new biophysical and socio-economic realities. In addition we need to develop an international perspective, with our neighbouring countries and globally.

Each of these plans was developed in relative isolation. To channel diversity, the editors propose a national research by design program that fosters collaboration, preserves diversity, and neglects competition. A truly national program that finances participation of scientists, spatial designers and delta professionals alongside policy professionals by pooling scientific, private and public budgets. A program that engages with stakeholders, policymakers and the general public and stimulates further integration of the natural, social and engineering sciences, with engineering practices and design.

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