Deltares

Deltares Mission-driven research

Activity Plan

2023

Foreword

This 2023 Activity Plan sketches the outline of the mission-driven Strategic Research that Deltares will conduct in 2023 with the SITO institute subsidy for applied research institutes. This Activity Plan underscores that the Deltares Mission of “**Enabling Delta Life**” is more urgent than ever to address major water and subsurface related challenges of climate change and adaptation, dealing with extreme events, keeping our water and subsurface healthy and productive, facilitating the energy transition and constructing infrastructure in a resilient way. These challenges have been addressed in international and national agendas and missions Deltares has adopted these as the basis for our programming to make a positive impact on society. To focus our research activities, we have grouped the missions and agendas into five moonshots providing the direction for our fifteen mission-driven programmes and knowledge facilities that we describe in this Activity Plan.

Contents

1 Challenges

Challenges

This Activity Plan 2023 outlines how the Deltares Strategic Research and the Knowledge Facility programmes aim to contribute to designing innovative and sustainable solutions for the complex and urgent challenges facing society. We will address the challenges related to climate change adaption, extreme weather events, healthy water and subsurface, biodiversity loss, energy transition and resilient infrastructure through a mission-driven approach, by co-creating and co-developing software, data tools and solutions with stakeholders and research partners to achieve societal impact.

These topics are more urgent than ever. The latest IPCC report has a clear message: climate change is visible worldwide and is intensifying. Consequently, it brings more intense rainfall and associated flooding, as well as more intense droughts. Further global warming will amplify permafrost thawing, the loss of seasonal snow cover, melting of glaciers and accelerating sea level rise. This is illustrated by the fact that impacts of climate change are daily front-page news as an ever more present danger: heat waves in India, the Mediterranean and the USA, forest fires, glacier collapse, prolonged droughts in Europe and China with resulting low water levels in rivers, and flooding events around the globe from the sea and rivers, like recent ones in Pakistan and Australia.

Greenhouse gas mitigation goals are difficult to meet. Therefore, the European Commission has put carbon management at the centre of its climate policy, committing to the goals of the Paris Agreement to limit global warming. Moreover, many of the UN Sustainable Development Goals tie into improving carbon sequestration and mitigation. Until 2050, the focus of the EU will be on mitigating greenhouse gases (GHGs), with a focus on CO_2 and CH_4 emissions. Another corner stone of the EU climate policy is climate adaptation. The European Green Deal set the blueprint for this transformational change that is needed towards a climate resilient society and to tackle environmental degradation on land, and to attain healthy oceans.

Worldwide, biodiversity is declining faster than at any time in human history with likely devastating consequences. The Global Assessment Report on Biodiversity (2019) and the Global Biodiversity Outlook (2020) stated that the biosphere, upon which humanity as a whole depends, is being altered to an unparalleled degree across all spatial scales. The recent IPCC report AR6-WGII specifically recognizes the link between climate change and biodiversity loss and the need to mitigate impacts on nature and climate simultaneously. The UN Biodiversity Conference scheduled in December 2022, will convene governments from around the world to agree to a new set of goals for nature over the next decade through the Convention on Biological Diversity post-2020 framework process.

Furthermore, the functioning of current infrastructure is under stress of intensified use. In addition, parts of the infrastructure are due for renovation or replacement and new infrastructure is constructed, such as the HWBP programme in The Netherlands. Changing climatic conditions challenge us for coherent assessment of our infrastructure networks to identify vulnerabilities in the system and to take effective measures now and in the future. Current flooding events in Pakistan with numerous casualties and refugees, shows the importance of a resilient critical infrastructure for evacuation, humanitarian aid and societal recovery.

Drought in Africa

Grass vegetation in Dutch dunes

All these global trends come together in the small deltaic area of the Netherlands. Urbanisation, energy transition, infrastructure renewal, intensive land and water use, agricultural transition, the restoration of biodiversity and nature and the need to adapt to climate change puts an increasing pressure on our available water and subsurface system and related ecosystems. These pressures are exacerbated by extreme weather events like the 2021 summer flooding in Limburg and the prolonged drought periods in 2018 and 2022, resulting in depleted ground water tables and record-breaking low water levels in the rivers Rhine and Meuse.

While climate change effects are visible now and demand interventions in the coming decades, it will not stop after 2050. Therefore, the investments of today determine the contours of the Netherlands for the coming 100 to 150 years. So, we need to look further ahead. The Dutch government has embraced ‘water and subsurface’ as guiding principles (coalition agreement 2021-2025) for spatial development and spatial adaptation. But what do these guiding principles actually mean? And how do we come to integrated decisions? Also, the Dutch Ministries emphasize the importance of an integrated approach to convergence all challenges in our Delta areas. On the one hand this is challenging, but these approaches may also provide opportunities to create new solutions. We can no longer look at separate challenges in a mono-sectoral way. Therefore in 2023 a diversity of experts will continue to work on the ‘Rethink the Delta’ initiative to enable solutions for delta life in the coming decades.

Besides climate change there are other dossiers that we need to deal with, such as the nitrogen pollution crisis in the Netherlands, which is about excess agricultural and industrial deposition of nitrogen in the protected nature conservation sites (Natura2000 sites). Moreover, the water quality of many Dutch waterbodies is poor and might not meet the Water Framework Directive requirements in 2027. It has made clear to us that drastic decisions concerning land use need to be made, in order to adhere to EU standards for environment protection and to stop further loss of biodiversity. And while the energy transition to renewable sources is well underway, the war in Ukraine has shown that we are still dependent on natural gas. The challenge is to accelerate the energy transition even more, while safeguarding sustainable use of the water and subsurface.

Society is struggling with the many transitions that need to be made. Because popular support for these changes is vulnerable, this requires an integrated, systemic approach in which we bridge in-depth excellent knowledge into comprehensive insights.

Deltares aims to use their expertise to contribute to solving these challenges from the water and subsurface perspective. We recognize that our knowledge needs further development, and we can be successful only by working together with clients, research institutes and private parties.

To structure its research effort, Deltares puts the global, European and Dutch agendas and missions in a central position in the thinking and activities of our organisation. Our ambitions to contribute to these missions and agendas is made more concrete in five ‘moonshots’: inspirational, directive targets to challenge ourselves to go to the limit.

These moonshots are the backbone of the Deltares Strategic Research activities in order to achieve societal impact. In 2023 we will structure our research activities around these moonshots. Every research programme has focussed their activities on one or more of the moonshots. The societal challenges adopted in

the moonshots require activities to better understand system behaviour on the longer term but also to provide solutions for today.

While further developing the moonshots, we will put extra effort on biodiversity, the carbon cycle and social values. Also, we will further align our work with relevant aspects of the Coalition Agreement. The SITO Institute Subsidy budget distribution over the programmes will be adjusted to reflect these challenges facing us and therefore to better meet the moonshot goals.

To achieve the ambitions of Deltares on the moonshots, active alliances with universities and institutes of higher education are essential. We will therefore intensify and expand these relations by facilitating new chairs and appointments. This is reflected in the assigned budget. We also assign more budget to the Digital Transformation on the acceleration of our main software products and strengthening our capacity in data and cloud technologies.

In this document we will outline our research activities funded by the SITO Institute Subsidy. Chapter 2 explains our mission-driven way of working. Here, the moonshots are described in more detail together with the storylines that contribute to achieving these ambitious goals. Chapter 3 describes the 15 research programmes, and the Knowledge Facility programmes that underpin our research. Finally, we specify the Financial Framework in Chapter 4.

1 **Deltas remain habitable,** even in the context of two metres of sea level rise, land subsidence and climate change

2 Making the world's population **safer from flooding**

"Moonshots are inspirational, directive goals to challenge ourselves to go to the limit with major importance for society. This can only be achieved by working together."

3 **Resilient and healthy water systems** for people and nature in 2030

4 In 2030, **energy from water and subsurface** will account for 75% of the energy required for sustainable collective heating systems

5 By 2040, **infrastructure construction, replacement and maintenance** will be fully resilient

2 Mission-driven working, moonshots and impact

The heart of the Deltares mission-driven approach is our ambition to make an impact on society by drawing on the power of our knowledge. We adopt the specific ambitions and missions from the national and international agendas through the lens of water and subsurface. To that end, we formulated so-called perspectives of “Future Deltas”, “Safe Deltas”, “Sustainable Deltas” and “Resilient Infrastructure”. In 2022, we made our ambitions more concrete using the concept of ‘moonshots’ relating to societal challenges, where we will demonstrate leadership in the years ahead with the emphasis on our impact on society.

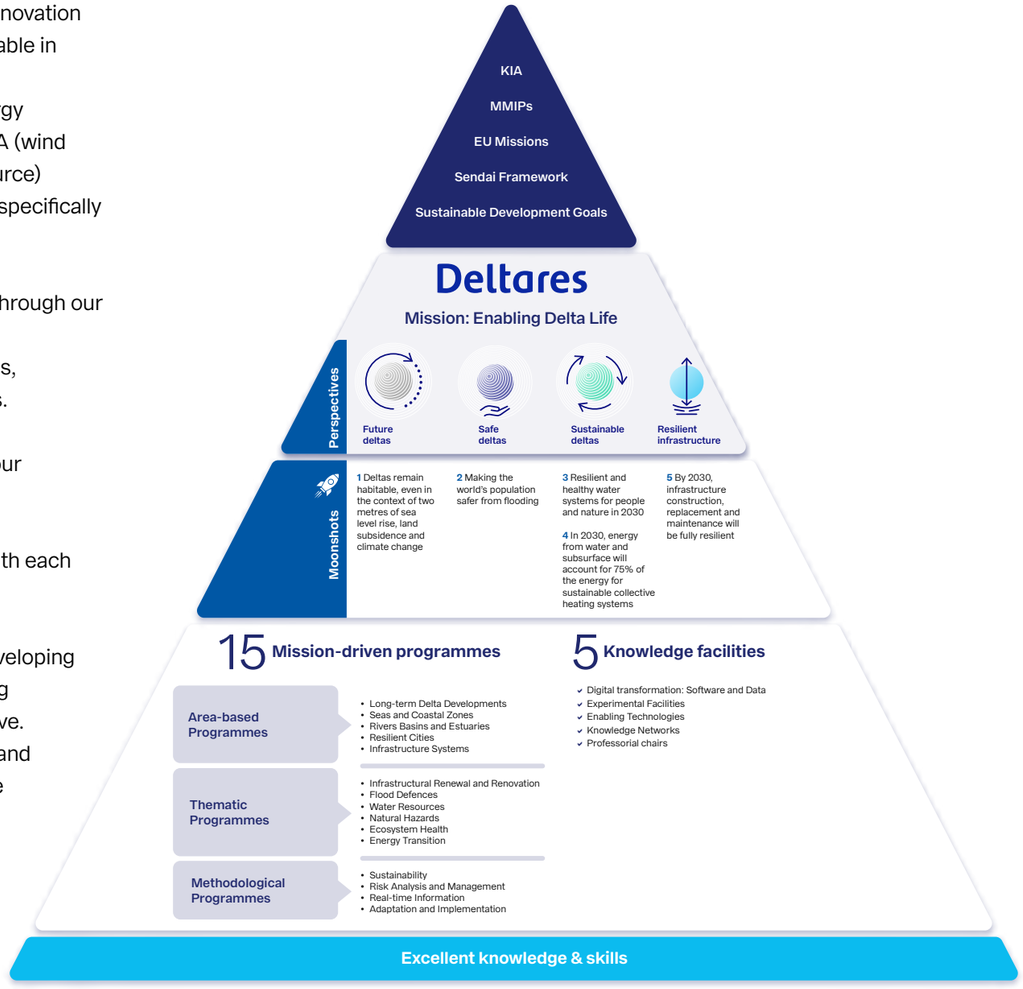
Our research is aimed at contributing to the Dutch national and international missions. We address the following of those missions:

- The Dutch Knowledge and Innovation Agendas (KIA for Knowledge and Innovation Agenda) composed by the Dutch Topsectors:
  - KIA “Landbouw, Water, Voedsel” (AWF for Agriculture, Water and Food supply), specifically Missions C on Climate-resilient rural and urban areas, E on Sustainable North Sea, oceans and inland waters and F on The Netherlands as the best protected delta, and specific MMIPs (Meerjarige Missiegedreven Innovatie Programma’s or Multi-year Mission-driven Innovation Programmes) within those missions. We refer to the Table in Appendix A for a full list
  - KIA “Energietransitie en Duurzaamheid” (E&S for Energy Transition and Sustainability), specifically on Missions A (wind energy), B (alternatives for natural gas as a heating source)
  - KIA “Gezondheid en Zorg” (H&C for Health and Care), specifically on Mission I (Lifestyle and Living Environment
  - KIA “Veiligheid” (Safety), particularly on safety at sea.
  - KIA ”Sleuteltechnologieën” or Enabling Technologies through our Enabling Technologies Program.
- The Sustainable Development Goals of the United Nations, specifically those related to water, climate, land and cities.
- The EU Missions, all missions except B
- The Sendai Framework for Disaster Risk Reduction, all four priorities.

The KIAs, missions and MMIPs we address are specified with each moonshot and are elaborated in the Table in Appendix A.

To increase the value of our research for society, we are developing our ideas for understanding, measuring and communicating societal impact and are continuously learning how to improve. In our organisation we are introducing new methodologies and adapting existing ones to our field and context. We continue exploring multiple impact pathways and are in the process of integrating ‘impact’ in our everyday activities. We work closely with our partners (national, regional, private and public) to discover what works and how to learn from each other. Lastly, we are collaborating and actively discussing with our users and clients how to further improve the uptake and actual use of our knowledge for innovative solutions to realize societal impact.

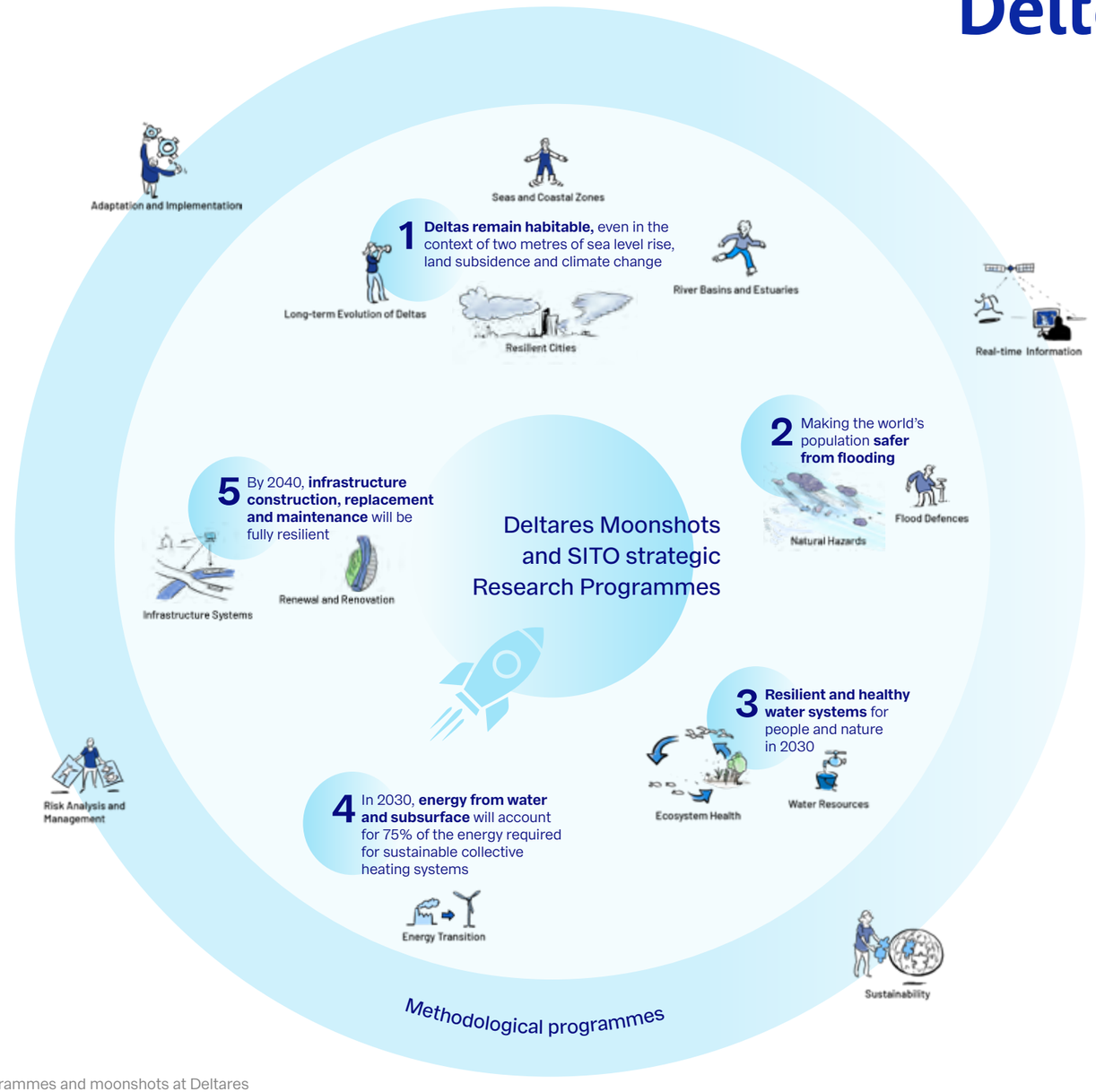
Mission driven working



National and International Missions, the Deltares Perspectives and Moonshots, and the Mission-driven Programmes and Knowledge Facilities.

Moonshots are inspirational targets that will provide direction for our activities in the longer term, will challenge ourselves to go to the limit and are an invitation to our knowledge partners to join us in this challenge. The moonshots are given a central position in how our organisation thinks and works, and in our alliances outside Deltares. We will be developing the moonshots further with our partners because they can be achieved only through collaboration. Working together, we will identify the new initiatives and collaborations that will be needed to achieve the moonshots and determine how we can link and strengthen ongoing initiatives.

With the Ministry of Infrastructure and Water Management we are joining forces as a strategic partner. Knowledge development and collaboration are crucial, both between The Ministry and Deltares, as well as with other partners. The research and innovation needs in these collaborations are driven by a long-term perspective and an integrated vision on challenges and missions. For this reason we are strengthening our joint programming focussed on these challenges. With our SITO Institute Subsidy, we build a knowledge base for the questions the Ministry and other governmental parties have. Building on this base, we are developing a separate demand-driven knowledge programme (SITO Program Subsidy). In this programme we work on widely accessible knowledge and tools, for the Ministry, other government bodies and private parties. The moonshots provide the direction for the development and growth our fifteen mission-driven Strategic Research programmes and knowledge facilities. This Strategic Research Activity Plan includes the initial elaboration of the moonshots and related activities. In addition to the SITO Strategic Research, also the SITO Programme Subsidy (Ministry of Infrastructure and Water Management), EU Horizon Europe projects, TKI projects and (international) market projects are aligned to the moonshots. In this chapter, the five moonshots are described and linked to the goals of the Strategic Research programmes for 2023.

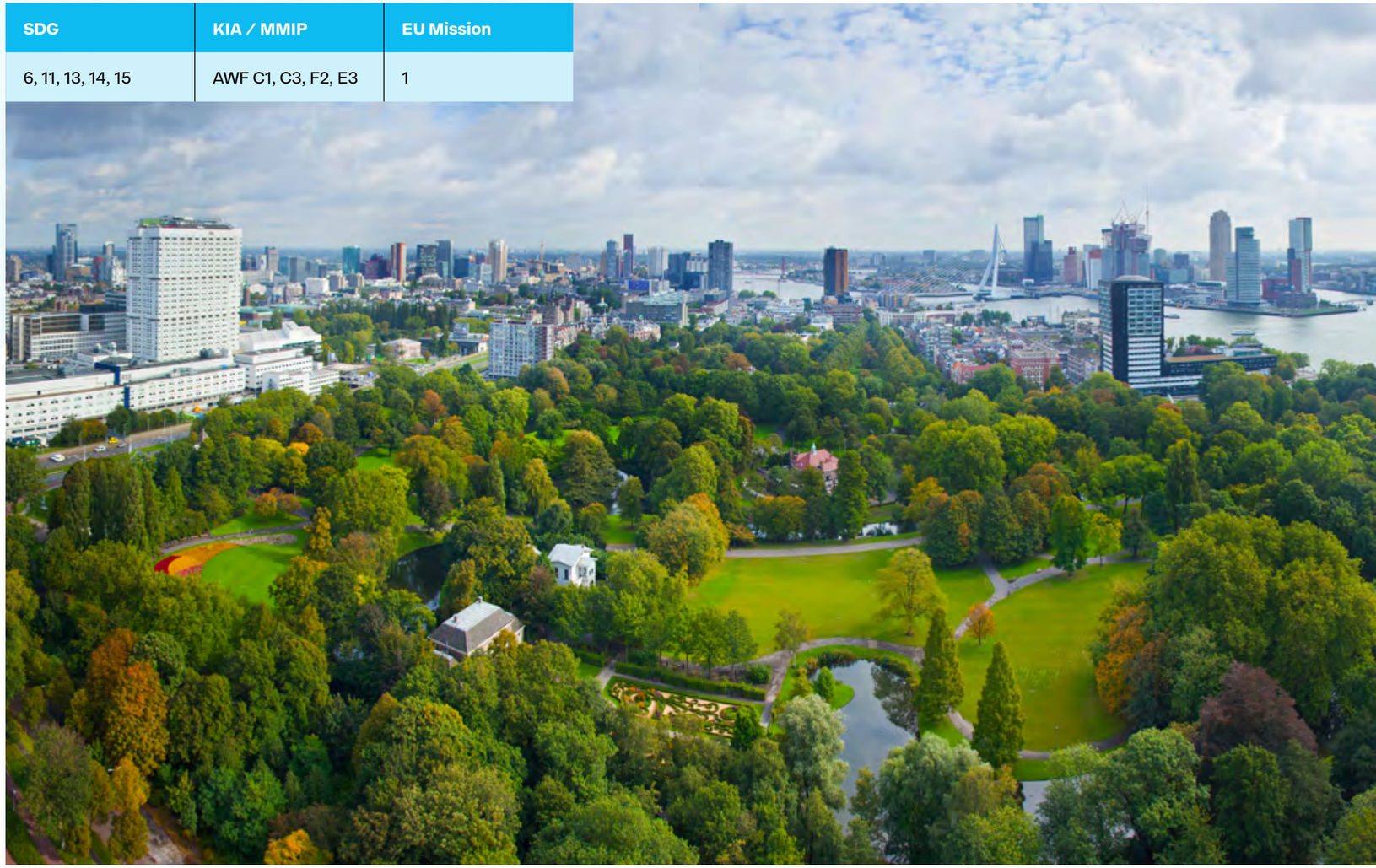


Mission driven Programmes and moonshots at Deltares

Moonshot 1

Deltas remain habitable, even in the context of two metres of sea level rise, land subsidence and climate change

SDG	KIA / MMIP	EU Mission
6, 11, 13, 14, 15	AWF C1, C3, F2, E3	1



View of Rotterdam

Deltas worldwide are facing complex planning challenges and a restricted solution space due to land subsidence, sea level rise and changing weather patterns due to climate change. In addition, deltas and low-lying areas are dealing with increasing urbanisation and spatial pressure on rural land use. These challenges require an integrated spatial planning approach that strikes a balance between living, working, energy, mobility, nature and agriculture in a changing landscape. In the Dutch Delta, we face the challenge of building one million houses in addition to other planning issues with major spatial consequences, such as the transitions in the fields of energy, agriculture and nature, and the replacement and renovation of large-scale infrastructure.

Knowledge of water and subsurface systems and understanding of future socio-ecological changes in densely populated delta areas are indispensable for the complex design task that follows. Deltares works on growing this knowledge base and develops innovative

measures to keeping deltas habitable while the land continues to sink, the sea rises, the weather and discharge regimes become more erratic, and we are also faced with a loss of biodiversity. Together with our partners some interesting and promising initiatives were taken as part of the development of this moonshot. See for example ReThink the Delta and Redesigning Deltas.

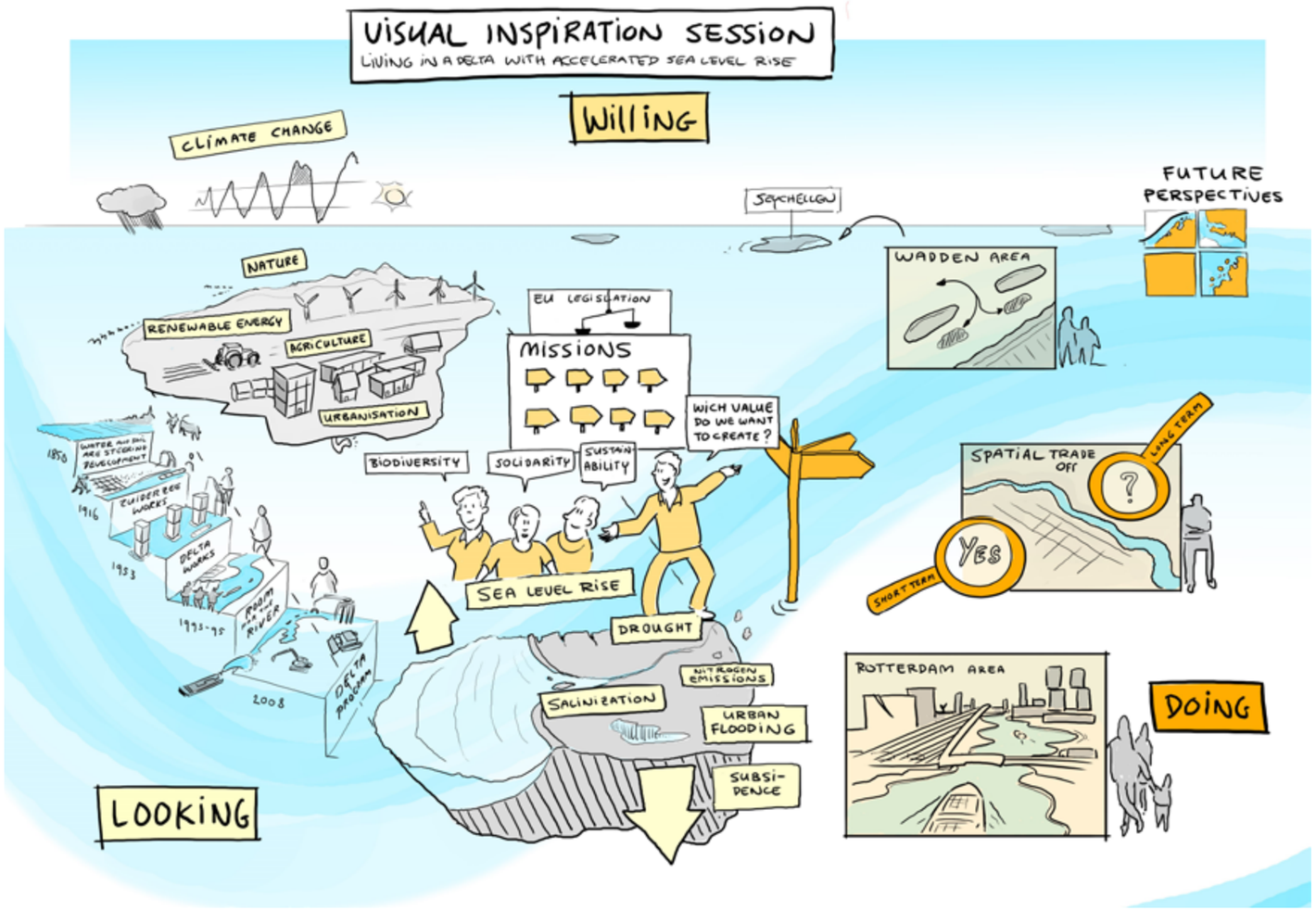
Understanding delta response to climate change

Long term physical developments of the Dutch Delta

The development of Dutch spatial planning and water management is a major challenge. We need to adapt to climate change impacts, while space to accommodate future opportunities is limited due to current pressures on the water system and environment. Knowledge of the physical and ecological systems are fundamental for sound spatial planning and to identify effective adaptation strategies.

Deltares investigates the long-term (2050 and beyond) physical development of the Dutch Delta, calculate and draw the impacts for different solution paths, and devise appealing presentation forms, resulting in delta stories that is envisioned to influence crucial decisions for the development of the Dutch delta, and this knowledge is also applicable to deltas worldwide.

In a multi-year iterative process, the SITO Strategic Research programme Long term delta development envisages for 2023 an updated status-of-the-delta report and an external symposium on the future state of the Dutch Delta (from a water and subsurface perspective). This is done parallel with the ReThink the Delta initiative (Moonshot 1). We will participate in public debates, advise governments, professional groups and interest groups, and train people in integral problem analyses and effective communication.



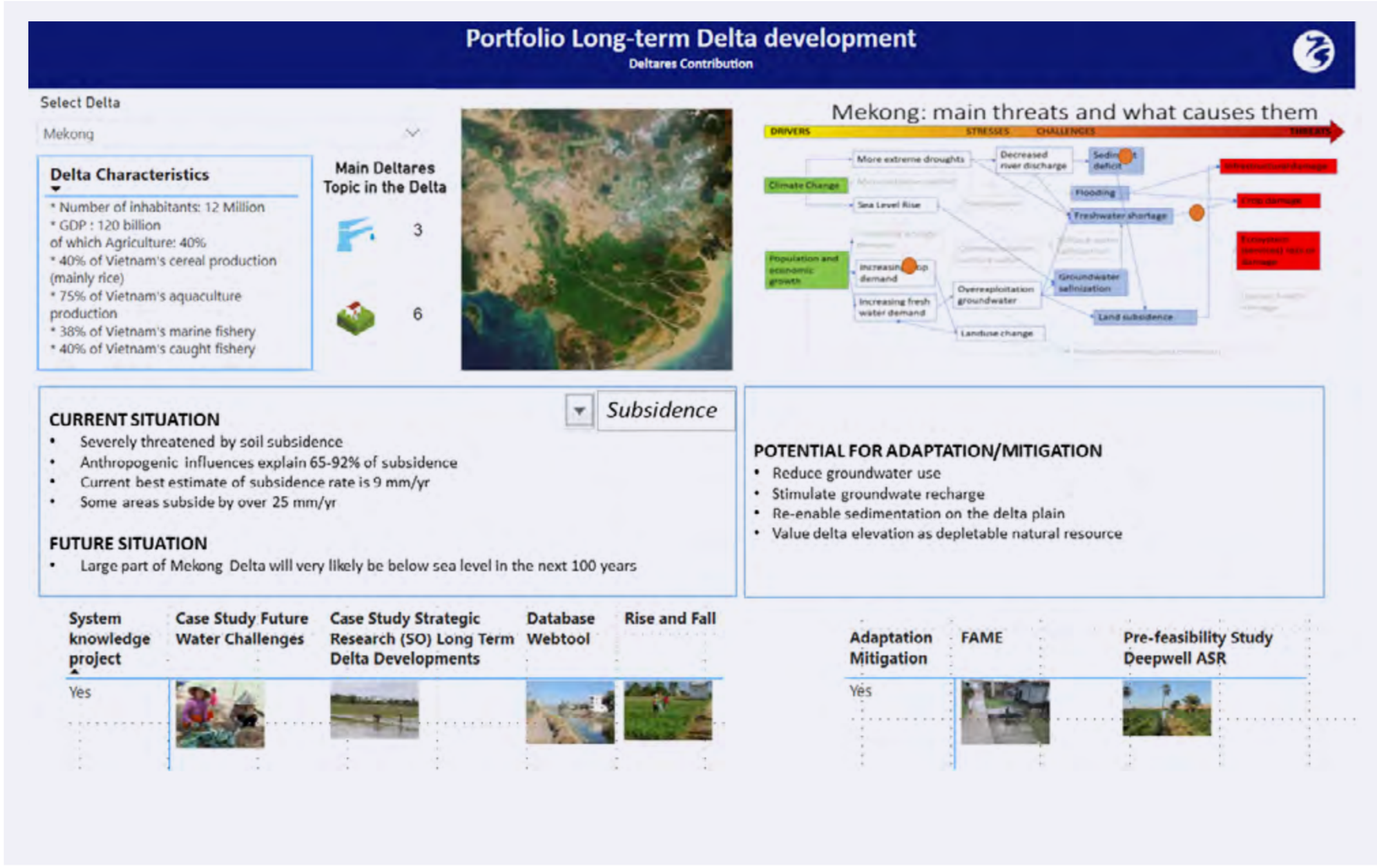
Concept drawing of the mission Habitable Deltas. The figure combines tasks and challenges (left) with an image of the role of Deltares' knowledge (center) to arrive at a collection of influential decision-supporting knowledge products (right). Source: Deltares

Expanding the Global Delta Portfolio
Deltares investigates and communicates the response of deltas to changing conditions. Here, we focus on developing global projections and supporting analyses for deltas worldwide that are identified as problematic hotspots. We take a multi-disciplinary approach to assess the interrelation between physical characteristics and socio-economic development while we also identify the timing and severity of future conditions.

For 2023, Deltares gives special attention to include socio-economic development and interaction with physical developments in deltas. We will combine and improve existing system knowledge with the insights from model predictions and make them available in a publicly accessible database. Information of the deltas of the Nile (Egypt), Ganges/Brahmaputra Meghna (Bangladesh) will be incorporated in this database. Knowledge dissemination of the long-term development of deltas will be done via a portal that depicts the available Deltares portfolio.

Method and tool development to investigate long-term changes
The data and knowledge of deltas worldwide are used to map, assess and present the consequences of the long-term (>50 years) delta changes due to e.g., sea level rise, climate change, exploitation of water and sand, construction of dams and other infrastructure. Within our models we determine the current and future status of environmental and human drivers, physical reactions, and their impacts.

We aim for organizations and governments worldwide to use our methods and tools to gain insights into the long-term consequences of climate change and socio-economic developments. This means taking long-term changes and development into account in the decision-making process of today's deltas.



Global Deltaportfolio

For 2023, we execute some of the suggested recommendations derived from the 2022 roadmaps on coast, salinization, and boundary conditions. Special attention will be given to link processes (morphology, groundwater, erosion, subsidence, etc.) to the FIAT methodology. In addition, we investigate how biodiversity is influenced by long-term delta change and vice versa.

Climate adaptation in river basins, rural areas, cities and seas

Resilient river basins

Both the regulated (e.g., Rhine-Meuse, Danube) and dynamic (Bangladesh, Egypt) river basins face huge societal challenges, among others climate change, population growth (more demand on limited space, and thus increase of risks), nature and biodiversity loss, ensure sufficient freshwater availability, energy transition and to maintain or increase the current landscape quality. Also, it is expected that future changes in the morphology and sediment transport could highly influence the (current and desired future) functions for both systems. Increasing the resilience of river basins through optimal river basin management is our guiding principle.

We strive for both scientific and societal impact. Our scientific impact will increase by becoming worldwide renowned knowledge partner on system knowledge of these river systems, including interactions between subdisciplines (e.g., navigation, nature, flood risk, water supply). To increase our societal impact, we develop assessment frameworks and knowledge on multiple solution strategies to ensure that a balance is achieved between functions and services of rivers, so that they will be managed in a sustainable way, while using and further developing the GOW (area oriented & societal challenge oriented) approach.

The knowledge of the system, methods and integral assessment frameworks support decision-making and planning by providing insight into possible synergies and trade-offs (natural, social and economic) of certain decisions and measures. When identified at an early stage, negative effects and processes can be prevented and the degradation of the soil-water-sediment system may be reduced. Currently, Deltares investigates how the system will evolve in the next decades due to the societal challenges. We assess how to operationalize flexibility and minimum regret to ensure that values of our future (desired) society are possible and how we can slowly transform to these values. With this information, we develop integrated assessment framework tools, such as the Sandbox, to help the decision-making processes in relation to the desired functions and services of regulated and dynamic rivers.

Spatial planning in rural areas

Rural areas face many transitions and challenges; the agricultural transition towards more sustainable and circular ways of farming, the water transition considering subsidence, drought and water surpluses and conflicting needs of water users (quality, quantity). Climate change, resource needs and the housing shortage impose extra pressure on the area and available space. Existing as well as newly planned infrastructure in these areas ask for adaptive measures on the short term and a more sustainable design on the longer term, driven by water and subsurface as guiding principle. But, how to organize such a transition towards a new design?

Knowledge is needed to tackle these various challenges while at the same time avoid and restore land degradation (due to drought and flooding, loss of biodiversity, sealing, contamination, and other threats). Deltares develops area oriented & societal challenge-oriented approaches in which knowledge of the system is combined with different adaptation strategies. By following the principles of “safe operating space for humanity”, we ensure that we’ll stay within the planetary boundaries of the water, soil, and ecosystem. This should be done in cocreation with the local stakeholders, linked to relevant programmes such as the Dutch National Program Rural Areas (NPLG), the national environmental programme (NMP, programme soil and subsurface) and principles such as “Water and subsurface driving spatial planning”.

Resilient cities

Public housing, climate adaptation, energy transition, mobility, circular economy are all challenges that come together in the city. In the coming years, cities around the world will be experiencing enormous transformations. Given the current spatial pressure, both above and below ground level, this will be a major challenge. With understanding of the urban system and long-term developments we can identify effective solutions for a sustainable urban water and soil system.

Deltares works on knowledge and evidence for sustainable solutions for the soil and water system in the city, to provide direction for spatial planning policy, standards for climate adaptation and guidelines for urban design. In addition to research (producing facts and figures), this requires intensive communication with various fields and attention to political and administrative developments. Within the Netherlands, we are making a prominent contribution to the extra effort needed to realise climate-proof housing.

The SITO Strategic Research programme contributes to answering the question above by researching the interactions between the water and subsurface system and (all) other urban aspects that depend on and/or are influenced by it. We translate the research results into practical tools and manuals. We use these results to transfer knowledge to stakeholders, contribute to cooperation

programmes that focus on integrated urban development, and to produce quantitative advice and guidelines for the construction and management of adaptation measures.

Spatial planning in the North Sea

The North Sea is one of the busiest seas worldwide. Oil and gas extraction, fishing, transport, surface mineral extraction, defence and recreation compete for scarce space. Cables and pipes run over the bottom and there are bases for wind turbines. The use of the sea is in transition. The government's ambition is to strike a good balance between the three major transitions to renewable energy, sustainable marine food production and a restored and robust ecosystem in the North Sea. This requires far-reaching sustainability of all existing forms of use.

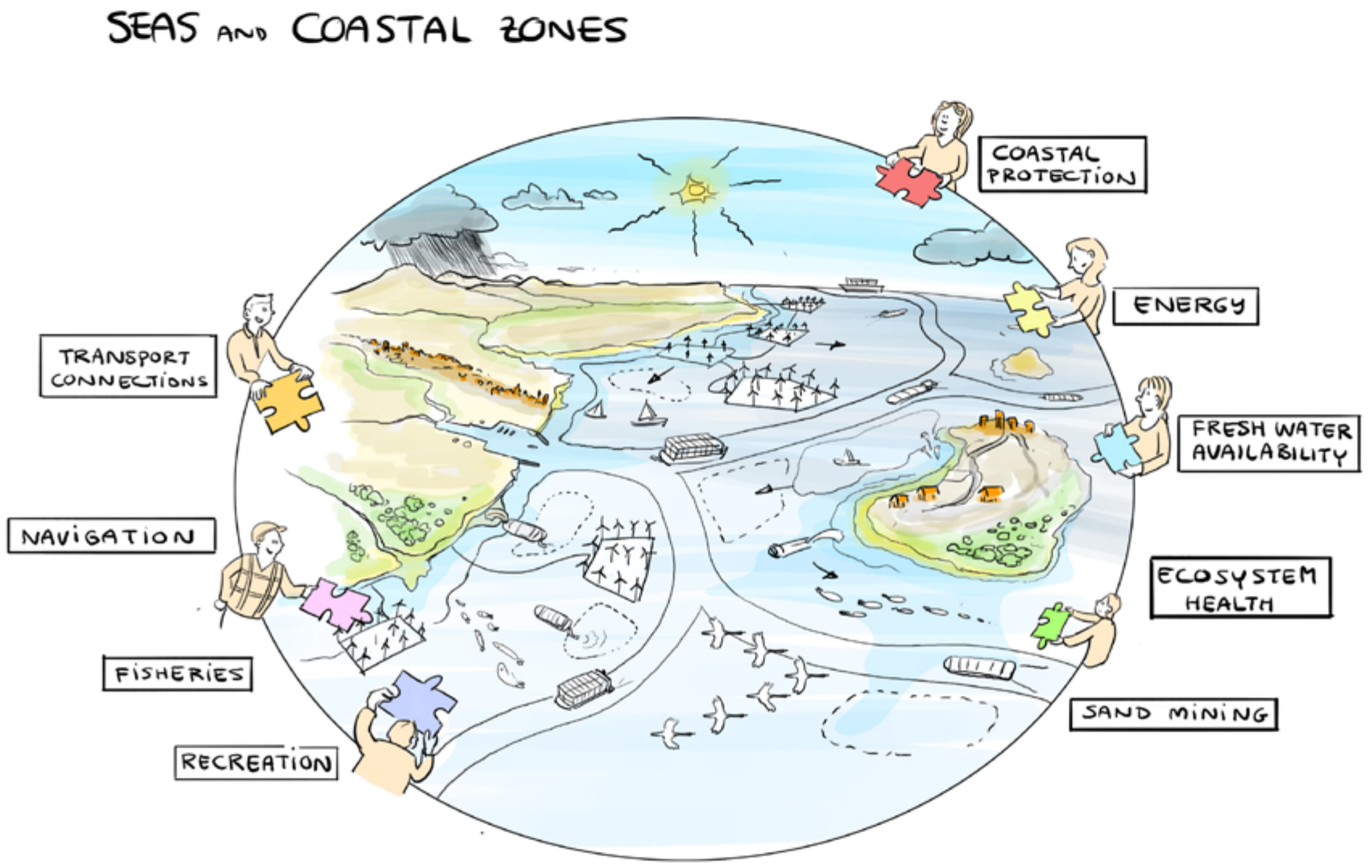
The SITO Strategic Research programme Seas and Coastal Zones contributes to the design, planning and management of the North Sea in a sustainable and safe manner by supporting stakeholders in integral assessments of marine spatial planning. We combine future scenarios in land use in the North Sea related to wind energy, sand extraction, aquaculture, shipping, recreation, fishing, etc. We investigate the future interactions of user functions and mutual effects to help planners and policymakers of the North Sea in their decision-making processes. We investigate the impacts of future use on the ecosystems of the seabed and in coastal zone, as well as solutions to conserve and protect biodiversity through nature-inclusive designs and/or other forms of co-use in e.g., windfarms. The Community Model North Sea is a central information hub for model results and observations and will play an important role in informing decision-makers as well as stimulating cooperation between the North Sea knowledge institutions. Knowledge is developed with 5 prototype multi-use pilot cases offshore to scale up sustainable solutions for multiple use of space in the North Sea.

Source: Deltares

Nature-based solutions to support societal challenges and transformative change

Nature-based solutions (NBS) are being promoted and supported widely for their ability to integrate different landscape functions and sustainable designs. Governments, investments banks and NGOs believe NBS are a key ingredient for making the world safer and more sustainable. However, we need to gain more knowledge on where and in what way the implementation of NBS is effective or not.

The SITO Strategic Research programme Sustainability will invest in a new narrative and vision on NBS that; (1) connects NBS to societal goals and multifaceted challenges including biodiversity, democracy, carbon and nitrogen cycling, droughts, floods and more; (2) provides a realistic perspective on where NBS is possible, and where not, the true extend to its contribution in solving the specific challenge at hand and what is needed to enable implementation; (3) goes beyond the single location application towards the NBS in relation to an entire landscape scale system. In 2023 the programme will initiate and develop a ‘NBS-from-2023-to-2300’ narrative together with partners.



Overview of North Sea functions. Source: Deltares

Moonshot 2

Making the world's population safer from flooding

SDG	KIA MMIP	Sendai
11, 13, 17	AWF C3, F1, F2, F3	1, 2, 3, 4

Flooding in Limburg, photo Geodata Hoogwater Limburg Het Waterschapshuis

Hundreds of millions of people worldwide are at risk of flooding from the sea, from rivers and from rainfall, with thousands of casualties and extensive damage and loss of wellbeing occurring each year. Due to population growth, economic development and climate change, these numbers will continue increasing in the future.

The Netherlands is at the forefront in protecting its people against flooding with a combination of infrastructure, policy, knowledge, funding and organisation. To keep the Netherlands well protected, existing water defences and water-retaining structures will need to be replaced as they age and water levels get higher. A driver is to reduce the costs of the replacement and renovation effort.

Internationally, we are committed to making cost-effective, suitable and equitable investments possible by governments and international financiers in order to protect people living in flood-prone areas. We play a leading role in the development and application of knowledge about the expected threats of water and wind, the

exposure and vulnerability of the population and infrastructure, and the short- and long-term consequences of disasters.

We accelerate our tool development and demonstrate our capabilities using two cases: rainfall-induced (pluvial) flooding in the Netherlands, and compound flooding due to marine surge, rainfall and river discharges in Beira, Mozambique.

We can make the world safer from flooding through 1) better understanding of extreme flooding, 2) development of effective and sustainable flood protection solutions, 3) effective and equitable flood risk management, and 4) useful disaster warnings and information. In this chapter we show in more detail how the Knowledge Programmes contribute to this moonshot.

Better understanding extreme flooding

Prevent or mitigate marine, fluvial and pluvial flooding and event-driven erosion

Every year, natural hazards resulting from extreme events affect 100s of millions worldwide. Deltares supports efforts to reduce impact through the development of better Disaster Risk Reduction (DRR) strategies. We do this through innovative research on the sources and pathways of (compound) natural hazards, the development of big data weather generators, the provision of data and development of models and tools such as SFINCS, XBEACH and HYDRO-MT to quantify future natural hazards, and the development of methodologies to quantify the effectiveness of DRR-measures.

For the Netherlands, we focus on understanding, quantifying, and measures to prevent (or mitigate) marine, fluvial and pluvial flooding and event-driven erosion to ensure that the Netherlands remains in

Moonshot ideation sessions at Deltares

the world's safest delta. Specifically, we contribute to the safety of our sandy coasts through research supporting the BOI programme, and on extreme river discharges through the GRADE programme and the KNMI'23 climate scenarios.

In an international context, this programme addresses flooding, event-driven erosion, landslide, and cyclone wind compound hazards resulting from extreme meteorological and geological events such as tropical cyclones and tsunamis, together with feasible, effective and acceptable reduction measures. We do this using the Globally applicable High-resolution Integrated Risk Assessment Framework (GHIRAF), that integrates models and tools to (quickly) evaluate hazards, risks, and measures. We test this framework in the US and Mozambique.

Effective and sustainable flood protection solutions

Reinforcing levees faster and at lower costs

As floods threaten lives, livelihoods and the natural environment, flood prevention through levees, dunes and storm surge barriers is essential, especially in the Netherlands. However, high investment costs, maintenance cost and other potential large impacts (such as required space) may hamper the development of this infrastructure. Therefore, there is a need to minimize investment costs and other impacts which is in line with the Dutch governmental missions and the Dutch HWBP HoogWater Beschermings Programma (Flood Protection Programme) that has the ambition to reinforce Dutch national levees faster and at lower costs. To this end, there is a need to estimate the failure probability of existing and planned flood defences which requires a thorough understanding of relevant physical processes such as (hydraulic) loads and (geotechnical) strength. Deltares' research helps to develop and optimize the toolbox for design and execution of reinforcements of flood defences to meet criteria related to budget, planning, societal impact and sustainability. We also strengthen the specific research infrastructures related to flood defences such as software (for example: artificial intelligence, emerging technologies, CFD modelling), experimental facilities (laboratories and field) and knowledge networks.

Effective and equitable flood risk management plans

Flood-resilient landscapes

To prevent flooding, levees, dikes and structures are essential elements. These levees need to have a very low probability of failure now and in the future, which sets requirements to size and height. As the same time, there are spatial constraints in densely populated areas. Deltares explores how to best integrate these flood defences in so-called waterveiligheidslandschappen, or flood-resilient landscapes. We provide insight into the impact that climate-change will have on the HWBP flood protection programme and on spatial planning of the flood protection system, including alternative and adaptive approaches.

Increasing the resilience of SIDS countries, their inhabitants and local ecosystems

Living on Small Islands Developing States (SIDS) are prone to multiple hazards which interact and may cause large damages and reduce the habitability. This will become an even larger challenge due to climate change, sea level rise and population growth. This means that the islands require innovative integrated solutions to protect the population against flooding and to ensure a sustainable healthy and clean freshwater supply for people and ecosystems. To achieve this impact, we focus on the development of integrated models and tools that can describe and quantify current and future hazards, damages and risks. The modelling tools include both the effect of storm events

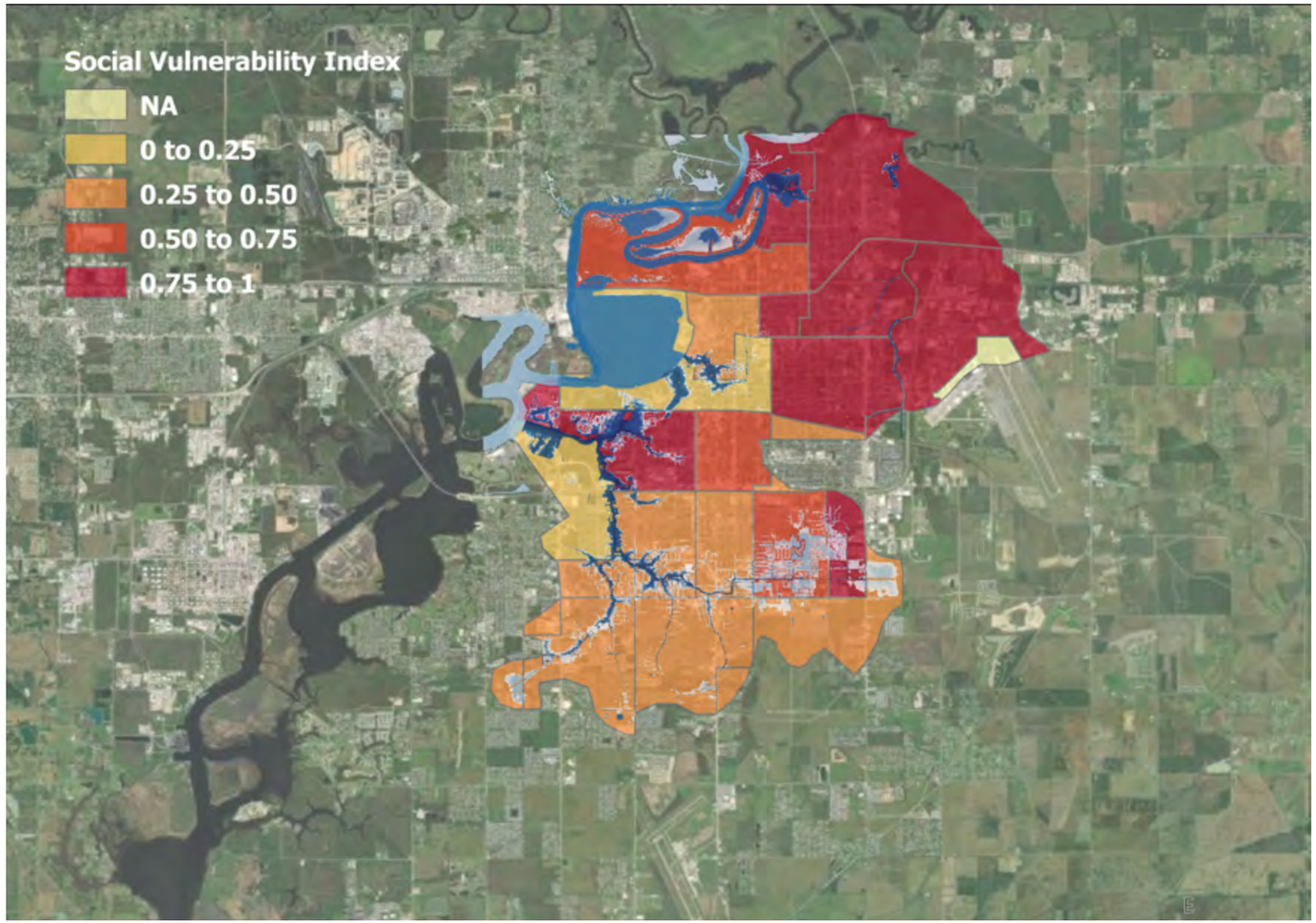
and long-term processes such as sea level rise, climate and socio-economic changes including migration. We explore the feasibility of flood mitigation strategies and measures to protect ground water aquifers.

Flood-resilient cities

A resilient city must do more than adapt the functioning of infrastructure to climate change. A city must be prepared to keep functioning during disasters and to recover quickly afterwards. This requires not only knowledge about the functioning of individual networks, but also about the interaction between networks and inhabitants. Using CRIDA (Climate Risk Informed Decision Analysis Approach), we are building a toolbox full of (automated) methods and tools (open source, and free to use) for different stages on the road to resilience. These stages are: 1) urban resilience analysis, where we use innovative software, monitoring and sensor technologies to analyse, map and monitor systems in urban regions; 2) Planning where we combine information from science, governance and design to integrate objectives and interests into a spatial plan or planning process, and 3) Implementation where we focus on physical measures for resilient delta cities, their implementation and performance. This is the input for the monitoring and evaluation cycle.

Inclusive approaches for flood risk reduction

When selecting measures to reduce the impact of natural disasters, relatively vulnerable groups in society should be included in the assessment (like social cost-benefit analysis). Deltares develops and improves climate adaptation methods that support risk-informed planning, including equity-based goals and a maximum level of risk for vulnerable communities. We cast these indices in tools such as the Delft-FIAT flood impact tool. An inclusive approach also supports successful implementation of measures, as it requires a local, inclusive and integral process for achieving real impact. We



Example of a “vulnerability index measure”. The index goes from 0 (not vulnerable) to 1 (very vulnerable). The map also shows flooding with a 100-year recurrence time

deliver instruments that the enable implementation of sustainable solutions for flooding so that technically-sound projects reach the implementation and monitoring stages with the support and involvement of local stakeholders and with equal benefit to the most vulnerable people. For example, the Adaptation and Implementation programme develops a stepwise approach to operationalize social inclusion into floods and drought monitoring and forecasting and planning at different scales.

Bridging the implementation gap

We explore which factors can hinder or delay the actual implementation of policies, programmes, plans or projects and how they can be influenced. This involves identifying and developing methods and approaches that eases implementation of policies, programmes, plans and projects into practice. We look at the overall enabling environment for implementation including legal and institutional frameworks, inter-agency collaboration, whole-of-society approaches, social inclusion and sustainable financing identifying real-life examples and lessons learned and developing method and approaches based in practice. We are working with governments in India and The Gambia to analyse their governance systems for the combined management of floods and drought and inform decade-long World Bank investment programmes in water and disaster risk management.

Surge forecast for cyclone Yaas, as visualized in BlueEarth Data

Useful disaster warnings and information

Global to local multi-hazard forecasts

Early warnings can significantly reduce the impact of extreme events, such as floods and droughts. Forecasting systems with global coverage can contribute to the Sendai Framework goals of making early warning available to all. This motivates Deltares to further develop globally applicable, locally relevant forecasting systems, including GLOSSIS and GLOFFIS. Based on these systems Deltares works towards a service-based dissemination of globally available multi-hazard forecasts, as well as automatically produced locally relevant information. This can provide a significant contribution to enhancing the protection from natural hazards of people living in deltas, especially in regions where this information is lacking, including large parts of Africa. In addition, this development is expected to generate new opportunities for more sustainable operational management in other sectors, including offshore, shipping, and agriculture. In 2023 we will further development of the global forecasting systems for storm surge, flooding, and drought, with special focus on integration of these systems to be able to address compound events, dissemination of the results through

High water in Bangladesh

Deltares services, and further development of the downstream applications aimed at producing locally relevant information, such as automatically generated local flood forecasts, and drought indices.

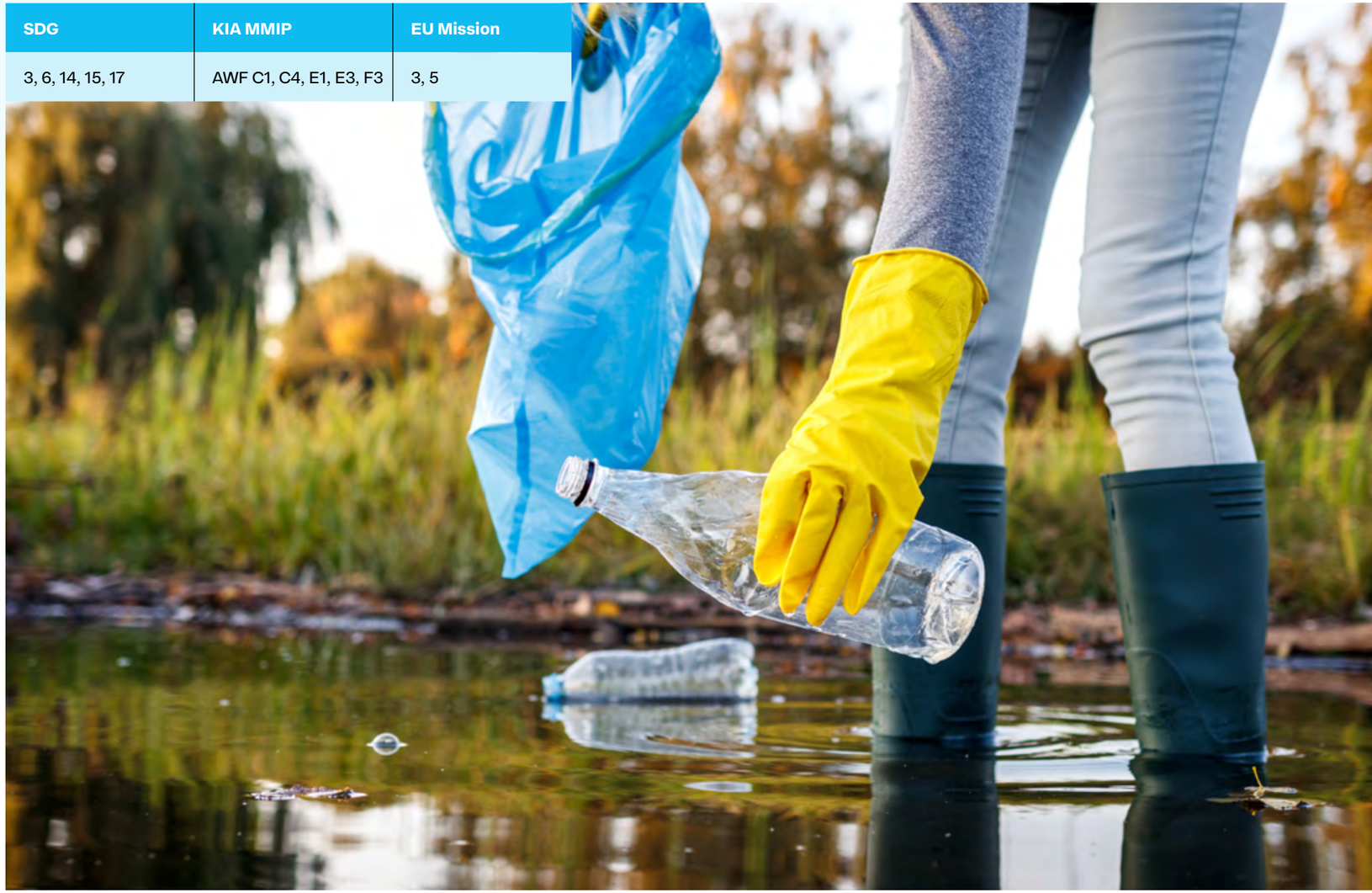
Urban and flash flood forecasting

Generating useful flood warnings for urban and flash flood prone area's poses requirements on the forecasting process that clearly differ from those in the large-scale, global approach. Both input data and underlying models need to be of high resolution, often ruling out open-source data (with global coverage). In addition, these systems are typically characterized by a fast response to meteorological forcing, with lead times being short compared to the runtime of numerical weather prediction models. In view of this, there is a strong focus on techniques such as radar nowcasting and rapid, high-resolution inundation models. In addition, the incorporation of local information for hazard assessment and mitigation is essential. This requires input of local stakeholders, who often have limited in-house forecasting capabilities due to the smaller scale of the organisations. In 2023 we will further develop radar nowcasting capabilities, rapid, high-resolution 1D and 2D inundation modelling, and investigating the potential of bespoke platforms for working together with the relevant stakeholders.

Moonshot 3

A resilient and healthy water systems for people and nature in 2030

SDG	KIA MMIP	EU Mission
3, 6, 14, 15, 17	AWF C1, C4, E1, E3, F3	3, 5



Water resources are under severe pressure worldwide and in the Netherlands – in terms of both quantity and quality – due to climate change and human activities. This is reflected by an increase in aridification, land subsidence, eutrophication and diffuse pollution in surface water and groundwater. Consequently, these changes are impacting ecosystems and biodiversity as well as agricultural productions systems. This also implies for the Netherlands and many other EU countries that we will not comply with the agreements in the Water Framework Directive and the Natura 2000 legislation. The EU Green Deal is therefore facilitating transformative changes in land use and water management to enhance climate resilient, ecological sustainable and societal inclusive sharing of water resources.

A transition to more sustainable management and use of water resources is needed to secure quality and quantity of water resources for nature and future generations. We strive to achieve climate-resilient water systems that are ecologically and chemically

healthy and managed sustainably so future generations will be able to use and enjoy them. Water use should not lead to the depletion of groundwater aquifers and surface water, or to poor water quality. To achieve such a transition, all relevant actors and stakeholders need to be involved. Also, water and subsurface should become leading factors in spatial planning.

Deltares contributes to resilient and healthy water systems through knowledge development for sustainable water-resources management, to improving ecosystem functioning and enhance biodiversity, improving water quality and preparedness for drought events. We make our data, models and decision methods available and adapt them to secure water supplies and healthy habitats around the world.

Sustainable water resources management

Deltares contributes to the implementation of transitions in water allocation regimes towards climate resilient, sustainable, equitable and economically efficient sharing of water resources, while supporting the sustainable development of water-dependent economic sectors. Within the SITO SO Strategic Research programmes, we contribute to knowledge base of nature-based solutions for sustainable water systems, raise awareness amongst stakeholders about their impact and support governments and NGOs with water management in poor, fragile and conflict contexts.

Nature-Based Solutions for sustainable water resources management

Nature-based solutions are increasingly considered as a strategic addition to the available solutions to prove secure and healthy water resources and nature for future generations. For example, the sponge function of landscapes to capture and store water during wet periods and releasing this water during dry periods is seen as an important ecosystem service that needs to be revived in those areas where these functions have been lost due to changes in land-use and management. This will allow for landscape scale resilience against extremes and changing climate, and at the same time ties in with the needed knowledge to provide a balanced evaluation taking also into account the expected impact of these solutions related biodiversity and green-house gas emissions and storage.

Deltares contributes to sustainable water resources management by delivering a better quantified underpinning of the role of Nature-based Solutions in reaching these targets. We work towards providing new examples and validated methods to quantify the role of nature-based solutions at landscape scales that are linking both groundwater and surface water systems for integrated assessments such as defining the role of ‘natural water retention measures’ for both floods and droughts, acknowledging the relevant co-benefits and trade-offs of individual measures within a larger integrated water resources management strategy where water and subsurface systems should guide the spatial planning. Aspects of food production, biodiversity and human health come into play in the design of measures to reach multiple goals within a single landscape.

From 2021 onwards we to invest actively in the putting the role of NBS for droughts in catchments and NBS in urban systems on the agenda, as these are systems where these pressures are strongly felt, both in The Netherlands and internationally, resulting in a growing portfolio on the topic, and will continue doing this in 2023 in cooperation with external partners

Supporting decision-making

Stakeholder awareness of the risks of climate change, water scarcity and water conflict are key towards a fair and sustainable use of water resources. The full economic impact of drought is difficult to quantify, but according to the EU’s Joint Research Centre (JRC), the current average cost of drought for the EU and UK alone is nearly €9 billion per year. The recent IPCC report on climate change notes that in some areas – including the Mediterranean, southern Africa and north-eastern Brazil – droughts are rapidly increasing in scope, duration and intensity due to climate change.

Deltares is committed to catalyse collaborative actions for water supply and use, and drought management planning and projects towards water resilience. The four-year EU horizon project STARS4Water will contribute to this ambition. Deltares (lead), together with partner institutions, will develop and deliver new data services and data-driven tools for better support of decision making and planning of actions for adaptative, resilient and sustainable management of freshwater resources. The project team will work with river basin organizations through a co-creation approach. The new services and tools will be co-designed with stakeholder communities to meet their needs on data and information and as accelerators for further upscaling of these services and tools to other river basins worldwide and beyond the lifetime of the project. We will make the new data services and tools available through our Blue Earth Platform.

Water resources management in poor, fragile and conflict contexts

Deltares is committed to support the implementation of resilient and sustainable water resources management. We contribute to integrated solutions that address multiple risks such as water scarcity, insecurity, migration and climate change in poor, fragile and conflict contexts. These solutions promote socially inclusive services for both refugees and host communities.

Deltares has pledged its commitment to the Global Compact on Refugees (GCR) in 2019. The GCR is an historical deal to ease pressures on host countries and communities and support displaced persons in their most immediate needs, while at the same time enabling them to build new productive and fulfilling lives. Deltares contributes to water security, water-related risks and protection of the environment in and around refugee settlements. We provide technical support in the preparation and implementation of water resource management and disaster preparedness plans and actions. Also, we support site selection for accommodating new refugees and forcibly displaced people considering the feasible capacity of the area in terms of availability of water resources and water and soil related risks. Deltares contributes to the knowledge base to secure water for all in and around refugee and displacement camps, to build resilient communities and understanding the water-migration nexus. To increase our impact, Deltares and the United Nations Institute for Training and Research (UNITAR) Maastricht facilitate two PhD positions to develop knowledge and tools that are adapted to the needs of the humanitarian sector.

Visual of future joint innovative drought forecasting system.

Preparedness for drought events

Supporting decision-making in extreme drought events is needed in more regions worldwide and more frequently due to climate change. In 2018, 2019, 2020 and 2022 large parts of Europe were struck by exceptionally prolonged periods of dry and warm weather, leading to widespread drought. In the Netherlands alone the related economic loss has been estimated to be in the order of 1 to 2 billion euros (2018), with nature, agriculture and (to a lesser extent) shipping being the most strongly affected sectors. In order to reduce the vulnerability of society to drought a total of 46 recommendations were made by the “Beleidstafel Droogte” (a forum of policy makers in the field of water management and droughts). Sharing of data and the availability of real-time information and drought hazard and risk forecasts are recognized as key factors that contribute to balanced decision making. Consequently, several initiatives have started to follow-up on these recommendations, but operational information has remained scattered and is in most cases not ready for decision-making.

Deltares aims to take the lead in bringing together the available expertise and tools. In 2023, we aim to further develop an innovative drought forecasting platform to test new developments related to drought forecasting and real-time information. Such a platform requires outreach, user management, configuration, and (possibly) software development, as well as the arrangement of infrastructure.

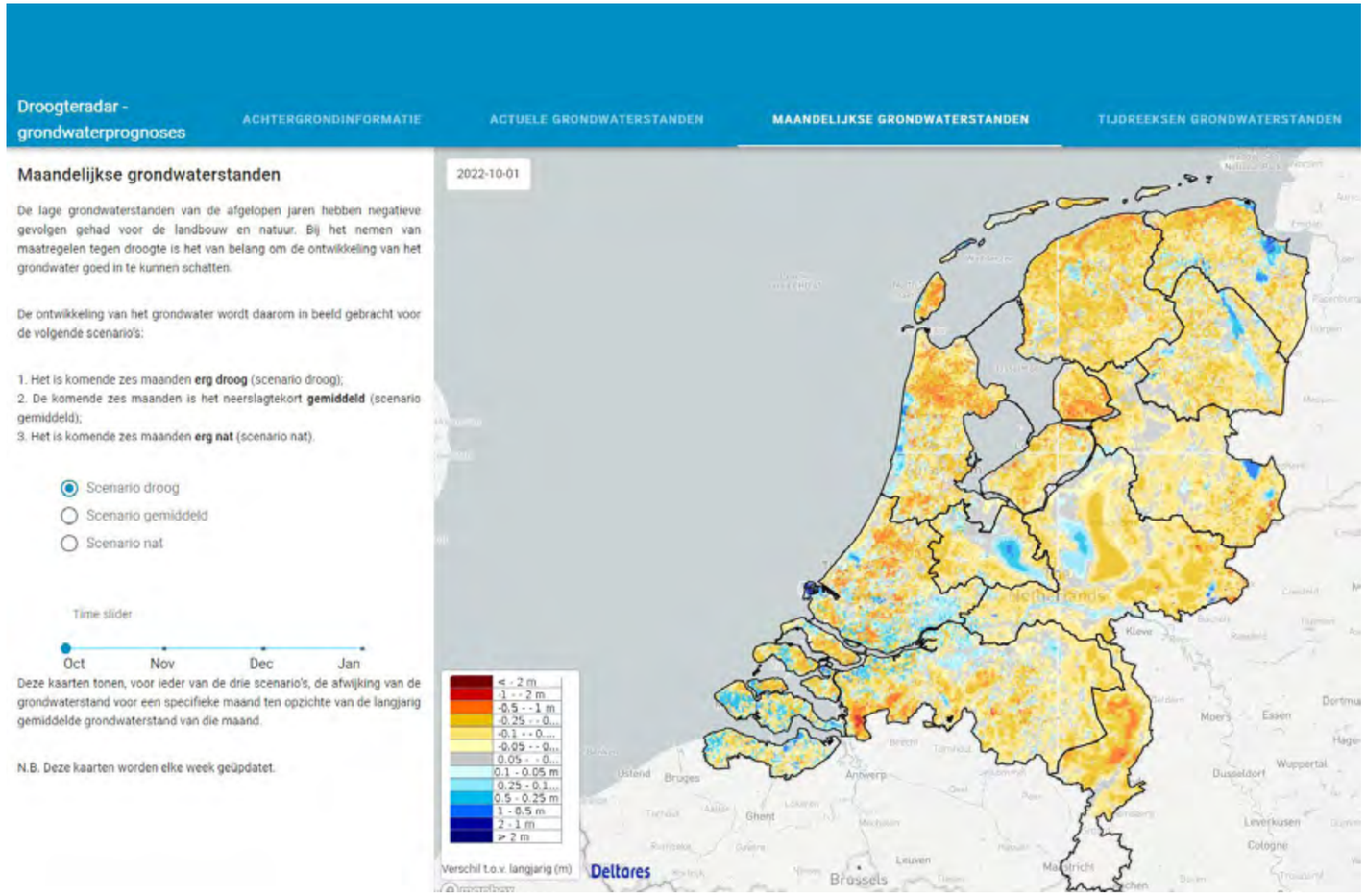
Other activities are the further development of state-of-the-art seasonal forecasts of the Rhine and Meuse catchment implemented in the innovative forecasting platform, and the development of state-of-the-art inland drought hazard and risk forecasts and real-time information, based on a combination of models and data, including groundwater levels (figure below), local stream runoff and soil moisture as well as (potential) impacts on nature, fire vulnerability, and agriculture. Last, we aim to develop a of state-of-the-art operational system for conjunctive management of groundwater and surface water.

Improving ecosystem functioning to enhance biodiversity

Providing support in understanding ecosystem functioning is a key-approach of Deltares in many projects. We develop knowledge for sound system understanding, to support the identification and implementation of effective and sustainable measures to restore and enhance biodiversity. Within the SITO SOStrategic Research programme, we work on restoring biodiversity and including ecosystems in water allocation schemes. With our system knowledge, we aim to contribute to restore and protect the biodiverse ecosystems of Dutch estuaries and lakes.

Restoring biodiversity

Healthy ecosystems depend on clean water, clean air, fertile land, a healthy and resilient ecosystem and a liveable climate. All these aspects are related to biodiversity. The loss of biodiversity that we are seeing all over the world can be regarded as a threat to life on Earth. The EU launched therefore a biodiversity strategy for 2030. The Strategy is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The



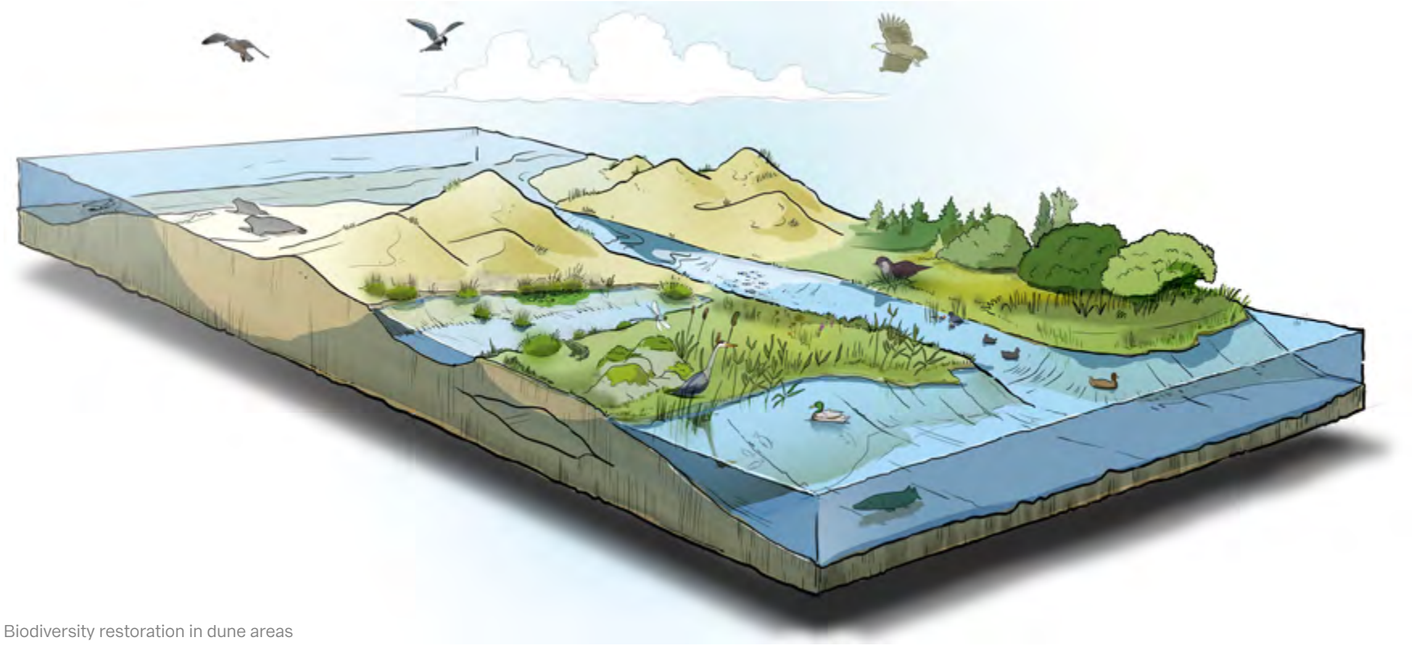
Screen shot of the droogteradar viewer, showing real-time groundwater levels (relative to 30-year average) as well as prognoses for the months ahead (under development)

strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments. Deltares wants to contribute to the restoration and conservation of biodiversity.

Many Deltares research themes are linked with biodiversity, like climate change, droughts, or energy transition. Increasing, restoring or preserving biodiversity strategies can benefit from our abiotic system knowledge and our predictive models and tools to determine habitat suitability and define proper methods for ecosystem restoration. Currently, our modelling tools are describing the interaction between the abiotic and biotic environment and assess the effects of interventions such as hydraulic infrastructures or nature-based solutions on these natural processes.

Deltares works on projects related to water, soil and infrastructure. These projects might intervene with aspects that determine biodiversity. For example: infrastructure in water systems – hydraulic structures – with the purpose of providing safety for habitants of the Delta or safekeeping freshwater for drinking water or irrigation. These structures might block crucial connections between habitats, cause disturbance for flora and fauna or add to water pollution by chemical substances. The sense of urgency to assess potential loss of biodiversity due to infrastructure renewal and renovation is increasing. Therefore, the impact of hydraulic structures on biodiversity will receive more attention within the research and project activities of Deltares. In 2023 we aim to further develop the Renewal and Renovation Infrastructure framework in which functional performance of biodiversity is also foreseen.

Lacking are tools and approaches that could quantify biodiversity loss and gain as a result of our projects. In 2023, Deltares will accelerate the development of approaches and tools to better address biodiversity in relation to our moonshots. Quantification tools for biodiversity loss are foreseen in the SITO Strategic Research programme in relation to Nature-Based Solutions, long-term development in Deltaic areas and resilient cities.



Biodiversity restoration in dune areas

Optimize water allocation

The intricate connection between water, energy, food and ecosystems (also called the WEFE nexus) leads to competition between different water using economic sectors, resulting in insufficient water allocation to support aquatic ecosystem functioning and biodiversity.

Addressing these challenges effectively requires cross-border, cross-sectoral, and cross-institutional approaches and cooperation. Deltares contributes to the design, planning and implementation of transitions in water allocation regimes towards climate resilient, sustainable, equitable and economically efficient sharing of water resources, while supporting the sustainable development of water-dependent economic sectors.

Deltares supports the Water Energy Food nexus and the links to other domains like ecology and health. In cooperation with national and international (knowledge) partners the programme contributes to the

understanding of cross-sectoral linkages, trade-offs and synergies and nexus solutions, in order to contribute to water-food-energy security in The Netherlands and other countries around the world, like Egypt, Bangladesh and Peru.

Dutch estuaries and lakes
Dutch estuaries and lakes accommodate international valuable ecosystems, and their biodiversity needs to be protected and restored. The Wadden Sea, Delta and Lake IJssel area, however, face societal challenges that affect their ecological functioning: climate change, population growth, and energy transition. For all three regions we want to know how the system will evolve, partially due to these challenges.

Deltares takes a regional approach to assess how all the desired functions and services can be combined, by providing insight into possible synergies and trade-offs (natural, social and economic) of decisions and measures. Because these synergies and trade-offs are identified at an early stage, negative effects and processes can be prevented and thus the degradation of the soil-water-sediment system. We are developing approaches and tools for integrated assessment of strategies to restore and protect international valuable ecosystems in our main water systems in the Netherlands, while considering other functions for society as well.

Improving water quality from source to sea

Water pollution due to chemicals, excess nutrient loads, microplastics and pathogens form a risk for human and ecosystem health. Deltares advertises a systems approach to assess water quality and pollution ‘from source to sea’, which includes the causes and sources that generate the pollution in the assessment. Deltares does not only work on the quality of water and soil in relation to nutrients, plastics and chemicals, but also on the emission of greenhouse gasses by (interventions in) wetlands and other ecosystems.

The quality of surface water and groundwater
The quality of surface water and groundwater is fundamental for the health of humans and ecosystems. Population increase, economic growth and climate change are affecting the quality of the environment. Also, adaptive and mitigating measures may have effects on it. The impact of insufficient water and soil quality is large, occur around the globe and insights into the quality issues are growing. There is a sense of urgency for a variety of sectors to improve water and soil quality. The quality of the water and soil is linked to challenges and transitions of society. For example, the quality of surface water and groundwater in the Netherlands is not improving fast enough to achieve the objectives of the Water Framework Directive in 2027. Another example is the ever-increasing amount of plastics that is used by humans and entering the environment.

Deltares is approaching environmental quality in a holistic way, by assessing the water and soil system and its development with modelling, monitoring and experiments, and developing knowledge to underpin and design sustainable solutions for healthy ecosystems. Our ‘from source to sea’ approach includes the causes and sources that generate the pollution in the assessment. By integrating our technical expertise with socio-economic information, we identify effective solutions that bring action perspective for the client.

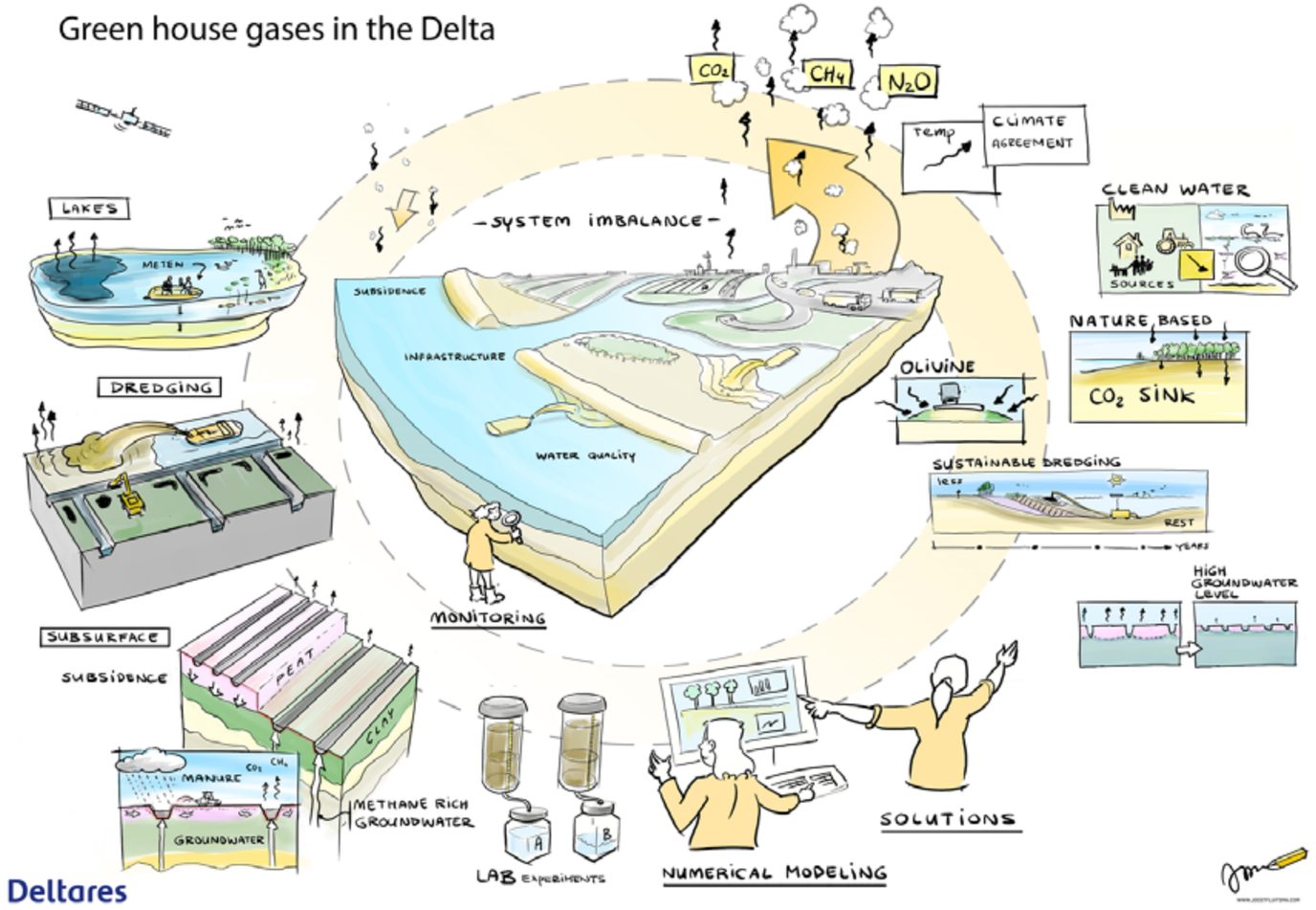
Deltares contributes to the knowledge development in European research projects. There, Deltares works together with the EU research institutes to gain insight on the drivers that affect water quality. The up-to-date information that is being used by the water authorities to apply the knowledge in their policies and for the implementation of the Water Framework Directive. We supports research activities aimed at

further development of hybrid modelling for real-time water quality. The knowledge on forecasting of water availability and quality may help to mitigate the impacts of ecologically unfavourable conditions.

Mitigating greenhouse gasses

Mitigating greenhouse gases (GHGs) challenges us to learn more about carbon sequestration and emissions by (interventions in) wetlands and other ecosystems. Many of the UN sustainable development goals tie into improving carbon sequestration and mitigation. For methane emissions, a separate track is setup within UNFCC. Until 2050, the focus of the EU will be on mitigating greenhouse gases (GHGs), with a focus on CO_2 and CH_4 emissions. As a result, there will be an increasing shift in research towards the potential of carbon sequestration to actively reduce the atmospheric CO_2 levels. Water managers are working hard to reduce their CO2 footprint, mainly through operational improvements. The hydraulic engineering sector is also looking for ways to reduce CO2 in their work. However, both sectors are not conscious of the potential emission reduction from water and sediment systems. According to estimates, emissions from surface waters contribute approximately 5% to Dutch emissions.

Greenhouse gas emissions from natural water systems is still a relatively unknown area and is complex in terms of processes (soil, gas, air interaction). Deltares' research activities and tool development contribute to a better understanding of the carbon cycling in relation to water management. Deltares has set up a team to better address these requests and to organize research on carbon cycling and the carbon cycle is part of multiple Strategic Research programmes. We developed a modest greenhouse gas emission facility in the past years which focusses on methane and CO2 emissions. We will build upon the BlueCAN project, were we investigated greenhouse gas emissions in small lakes and canals together with Witteveen+Bos, several water authorities and STOWA.



Green House Gases in the Delta. Source: Deltares

Moonshot 4

In 2030, energy from water and subsurface will account for 75% of the energy required for sustainable collective heating systems

SDG	KIA MMIP	EU Mission
7	AWF E1, F4, E&S 1, 4	4

The Netherlands and the world are facing a major challenge in terms of producing renewable energy. One of the goals of the climate agreement is to disconnect 1.5 million homes off gas by 2030. The expectation is that the heating for 700.000 homes will come from sustainable collective heating systems by 2030. The water and subsurface system can play a major role. It is our Deltares' ambition to provide the knowledge so that 25% of the sustainable heating systems is from water and 50% through high temperature storage or geothermal energy from the subsurface by 2030. In addition, we want 50% of these systems to use smart design, construction and control. Water and subsurface play an important role as a heat source (as in aquathermal and geothermal systems) and as a storage and transport medium (as in aquifer thermal energy and high temperature storage).

Using water and the subsurface for the heat transition has ecological and spatial effects on the water and subsurface system, the negative effects of which must be minimised. The challenge will be to safeguard sustainable use and to ensure that spatial assimilation in the urban area is feasible. This requires construction methods that result in less disruption and fewer costs for society. Deltares will supply knowledge and expertise to design and manage sustainable collective heating systems from water and subsurface energy on resilient lines, firstly in the Netherlands and increasingly in the rest of Europe. We develop solutions for the sustainable use of water and subsurface as a source and for the storage of heat and cold. We will take a leading knowledge position in upscaling, making sources and storage more sustainable, and cost reduction.

Utilizing water and subsurface resources in the heat transition

Heating and cooling in the built environment
In 2023 we will scale up and accelerate the heat transition through cooperation with all actors and a strong knowledge ecosystem. Joint efforts are required from various government levels, businesses, consultancies, housing corporations and citizens. With this we want to structure and improve the heat value chain of sustainable collective heating and cooling systems. Water and subsurface play an important role as a heat (and cold) source (such as in aquathermal and geothermal energy) and as a storage and transport medium (such as in heat-cold storage and high-temperature storage). Deltares will take up a leading position in system integration, both technical and societal, making source and storage more sustainable, and reduce costs. Deltares also contributes to the acceleration and upscaling of the heat transition with minimizing its impact on the electricity network. And works on minimizing ecological and spatial impact on water and soil system. Also, the cost-effectiveness of construction methods is addressed in order to cause less nuisance.

The challenge for the upcoming years is to integrate collective heating and cooling systems with solutions for climate adaptation, urbanisation, healthy and biodiverse ecosystems creating liveable and resilient cities. And to guarantee sustainable use and to ensure that the spatial integration in urban areas is feasible. Working with parties from the heat value chain with their specific experiences and knowledge, guarantees direct testing and using of the products and tools. Elaboration takes place in the innovation programme WarmingUP (2020-2023) and realization programme NieuweWarmteNu! (2022-2027). WarmingUP works on system integration connecting all links in the chain, while NWN! aims to accelerate the realization of sustainable collective heat systems by financing the unprofitable top of these systems and removing other bottlenecks; learning by doing is the adagio.

Towards a robust and sustainable electricity system
In order to mitigate the climate change, it is required to have a CO2-emission free energy supply in 2050. In 2030, 70% of the electricity will have to come from renewable resources, mainly supplied from wind and solar. This implies replacing existing fossil sources of electricity but also considering the increase of demand due to electrification in mobility, increasing use of heat pumps and demand for green hydrogen. Because of the e.g., weather dependency, measures are needed to properly connect the time varying supply and the demand. Connecting the energy markets within Europe with reliable energy infrastructure is crucial. Deltares will support this transition.

The energy transition and climate adaptation together will determine the new contours of the Netherlands (2050-2100). The impact on the environment will be significant. The solutions for the energy transition that will be developed and implemented in the coming decades must consider long-term developments, a sustainable delta with challenges of significant sea level rise, subsidence, more extreme weather situations, etc. Deltares stimulates the cooperation and facilitates the discussions between key players in the energy transition and climate adaptation in order to set the right steps forward.

For an acceleration in the developments of the energy transition, it is crucial to integrate the heat transition and the electrification. In 2023, further steps will be taken towards this integration by investigating Deltares contribution to the hydrogen industry, storing electricity in the form of heat and connecting supply and demand of energy.

Upscaling offshore wind energy production

In 2023, Deltares will be working on innovative solutions for offshore wind focusing on cost and risk reduction and optimization (safe and affordable scaling up). We will study proof of concepts of new foundation technologies (installation and decommissioning), guidelines and manuals concerning ‘scour’ and erosion, insights and knowledge about failure opportunities and mechanisms of offshore transport cables, multi-use and offshore demonstration pilots within the EU. Furthermore, the project portfolio is working on floating solar at sea and inland waters.

The North Sea is expected to see a major change and increase in human use over the next few decades. The energy transition will

claim significant areas on the North Sea dedicated to offshore wind and possibly in the future also offshore solar. The food transition sees a change from fisheries with bottom trawling gear to extractive aquaculture (seaweed and shellfish). Under EU guidelines there is a large national and international drive to restore lost biodiversity, ecosystem functions and keystone species. Besides these directly human-induced changes, climate change will also impact the ecological functioning of the system. In 2023 we continue to work on the Deltares suite of data science, modelling and monitoring tools as a basis for identifying and quantifying the complex interactive processes, governing impacts of human interventions and the ecosystem on the North Sea.

These developments are essential to optimize the North Sea contribution to the social foundation (energy, food, safety) while preventing the transgression of the ecological boundaries of the North Sea. As described under moonshot 1, in 2023 Deltares investigates the future interactions of user functions and mutual effects using the North Sea Community Model to help planners and policymakers of the North Sea (in the Netherlands but also neighbouring member states) in their decision-making processes.

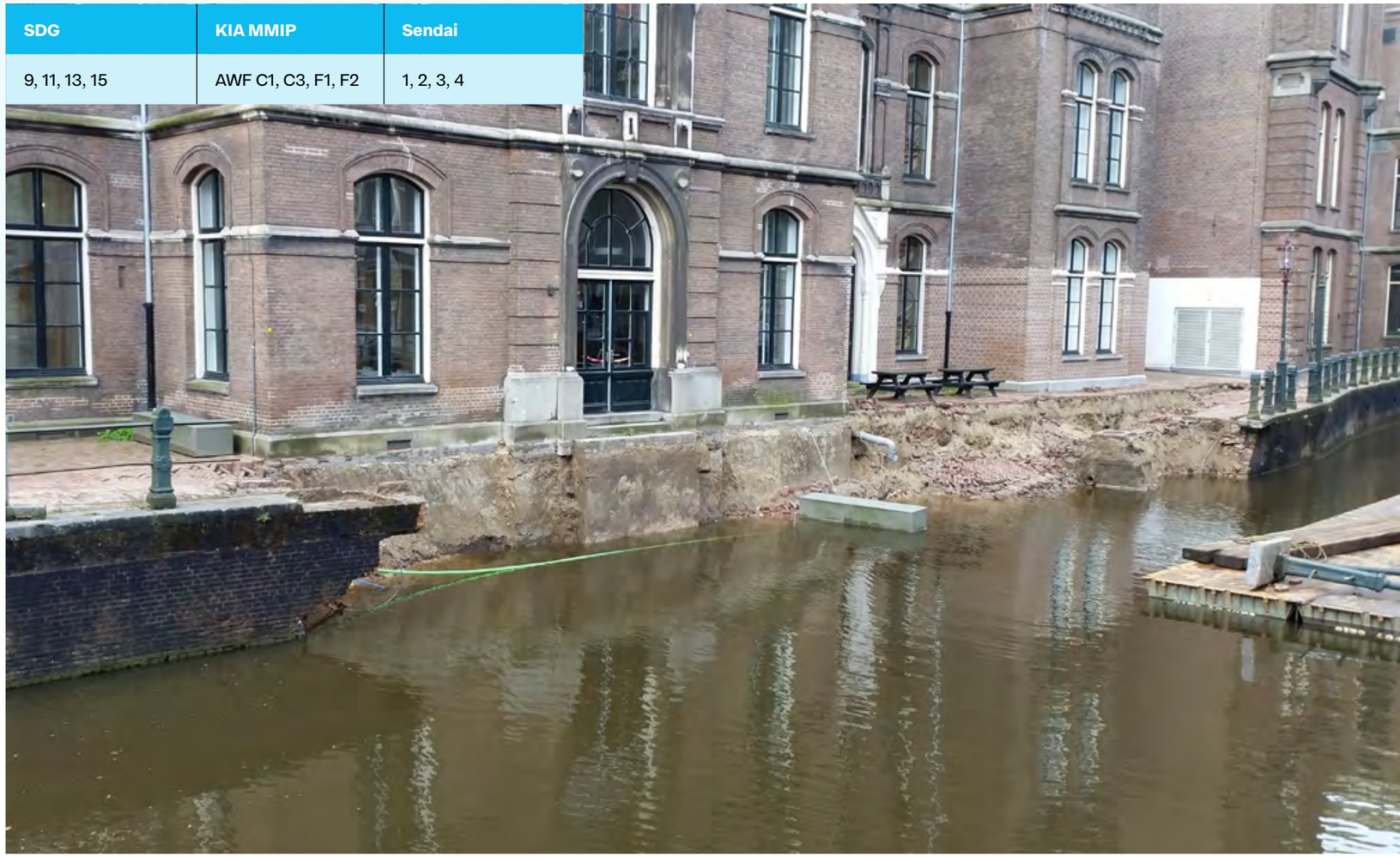
District heating distribution pipes

Moonshot 5

By 2040, infrastructure construction, replacement and maintenance will be fully resilient

SDG	KIA MMIP	Sendai
9, 11, 13, 15	AWF C1, C3, F1, F2	1, 2, 3, 4

A large part of the infrastructure in the Netherlands was designed and constructed in the 1940s and 1950s and is due for renovation or replacement. Partly due to aging, partly due to increasingly loads. In addition, the construction of infrastructure is inherent to urbanisation and the need for energy transition. These developments mean that we are faced with a major, urgent transition, in which we can no longer rely on the traditional approach. To make the transition a reality, resilient infrastructure is indispensable. National and international agendas confirm this. Resilient infrastructure maintains its function as much as possible - even under extremes - and recovers quickly, while it is flexible enough to adapt to changing social needs and uncertain climatic conditions. The question is: when is resilient resilient enough? What service level is accepted by society? Water and the subsurface play a guiding role in this. Now and in the future.



Quaywall Grimburgwal in Amsterdam
Source: Ceescamel, CC BY-SA 4.0, https-//commons.wikimedia.org

Deltares develops and disseminates knowledge in the field of water, subsurface and infrastructure. Deltares looks at the functionality of infrastructural objects and networks in relation to each other, from the perspective of coherence. From that perspective, it brings together the knowledge of stakeholders: the government, the business community, start-ups, knowledge institutes and NGOs. So that the sustainable, social and economic impact of construction, replacement and maintenance is taken into account in decisions.

It is of great importance that infrastructure is viewed from an innovative perspective, whereby the limits of our water and soil system provide guiding principles. The decisions made in different phases of the life cycle determine how an infrastructure object or network functions. The development of resilient infrastructure challenges us to accept that a design may fail more often, but that we limit the damage of that failure as much as possible. And on the other hand, we strive to maximize the social benefits of the infrastructure. This means, for example, that infrastructure is optimally integrated into the environment. In addition, it is also important that existing infrastructure continues to function during this transition.

Until 2030, Deltares will improve the decision information needed to make choices aimed at resilient construction and adaptation of infrastructure. We align our knowledge with the knowledge needed in decision-making processes. We test and improve our decision information based on increasingly better data, projections and methodologies. Consider, for example, digital twins. The boundaries of water and subsurface challenge us to make optimal and sustainable use of the possibilities of the natural system.

By 2040, if infrastructure is designed, constructed and maintained in a resilient manner, this will offer the possibility to balance interests and make decisions at any time based on the then prevailing circumstances - in the field of the infrastructure's life stage, population growth and climate change. At the lowest possible cost and with optimal sustainable, social and economic results.

Dealing with uncertainty and risk in infrastructure development

Risk-based prioritization, choice and design of measures lead to optimal use of scarce investment resources in the challenge towards resilient infrastructure. The important components of risk-informed decision information are the characterization of hazards, the reliability and availability of networks and assets, and the quantification of consequences in the event of failure of (critical) infrastructure. In order to facilitate the generation of the decision information, Deltares develops methods and tools, which can be used in different domains, such as reliability analysis, probabilistic modelling of subsurface properties or risk-based design concepts for coastal construction works (e.g., breakwaters).

The method and tool development enables practical use of the mentioned techniques in domains such as flood defences, port infrastructure, coastal engineering, (rail) roads, as well as by drawing up guidelines and adapting regulations. The use of these methods will eventually lead to optimal use of existing and the collection of new data, and thus to reduced uncertainties and a picture of the reliability and availability of infrastructure networks and assets. This enables safe use of ageing infrastructure and prevents unnecessary interventions. At the same time, the decision information facilitates cost-effective measures in terms of risks and uncertainties, also with regard to climate-proof design.

Support investment decisions on hydraulic and retaining structures

Deltares supports managers of water infrastructure in their investment decisions about aging assets. How and when to renew and/or renovate these as part of a strategy towards a resilient network? By developing an assessment framework, we merge the technical, functional and economic impact of interventions into an overview, enabling to prioritize options based on their future-proofness. Input for the assessment is the (changing) technical and functional performance of structures within the network. In 2023 parts of this framework will be developed in co-creation with RWS, MARIN and TNO (within the knowledge programme on hydraulic structures) and we will explore the opportunities of data driven decision making for these structures. In 2023 we will continue to work on salt management in locks through case studies and a system approach, as well as fundamental and applied research on bed protections. In co-creation with the community and problem owners (municipality of Amsterdam, Port of Rotterdam) we will continue to make steps on aging quay walls and sheet pile walls, for instance in the UrbyQuay project.

Hydraulic structures are important assets to organize a liveable and safe society, a healthy water system and smooth and safe transport. In co-creation with water managers, knowledge institutes, companies, universities and other Deltares develops knowledge that is needed to cost-efficiently maintain or improve water infrastructure, even under changing societal and climate conditions.

Reduce cost and environmental impact of infrastructure construction and maintenance

As mentioned before the Netherlands, Europe and other parts of the world face an immense asset management challenge. Deltares develops knowledge on how to embed existing and new infrastructure in the water and soil system. We develop this knowledge in cooperation with other parties: asset owners, users, designers and contractors. With this approach we aim to increase the uptake of our knowledge in practice. The objective is to equip our stakeholders with the knowledge, measures and tools to make decisions on investments in construction, operation and maintenance of reliable infrastructure at acceptable societal and environmental costs and with acceptable risk of failure.

In 2023 Deltares works on climate-robust and living breakwaters: we intend to increase the solution space beyond engineering solutions to nature-based solutions (such as reefs and vegetated foreshores). Apart from climate change adaptation this contributes to increased biodiversity. Also, we will start working on the effects of climate change on soil-structure interaction: Due to the effects of climate change, the behaviour of soil and soil-structure interaction will change. Deltares will further explore how this may lead to negative impacts for infrastructure networks. Special attention will be given to the effects of heat stress and heat interaction.

Dealing with land subsidence

In the past years, steps have been made in strengthening the knowledge base for dealing with land subsidence. Research programmes, such as Regiodeal Bodemdaling Groene Hart and Nationaal Onderzoeksprogramma Broeikasgassen Veenweidegebied,

Land subsidence in Gouda

have developed ways for dealing with land subsidence in peat areas in the Netherlands. In urban areas subsidence can cause damage to infrastructure and buildings. Whereas in rural subsidence causes less height and consequently higher ground water levels with consequences for agriculture. Meanwhile peat oxidation leads to increased greenhouse gas emissions.

Over the past years Deltares has been measuring land subsidence and related soil parameters in the peat areas in The Netherlands. With increased understanding we are able to predict and advice on the effectiveness of measures to deal with subsidence. An example is the constantly improving national subsidence prediction map. In 2023, Deltares will further improve our understanding of the mechanisms of peat and clay consolidation. We will refine model descriptions in order to improve subsidence predictions. Also work on the estimates of subsidence-related damage to infrastructure will continue. Specific attention is paid to knowledge utilization and implementing policies on subsidence. For example, in the 'Regionale Veenweide Strategieen' of the Dutch Provinces. Eventually the ambition of these provinces is to decrease subsidence by 70% in 2050 and the greenhouse gas emission to neutral in 2050.

Working towards resilient infrastructure networks

In various projects Deltares contributes to a climate resilient transport system and underlying networks (ports, waterways, roads, railways, cables and pipelines). We develop knowledge on embedding transport infrastructures in the water and soil systems and on how these infrastructures contribute to climate resilient spatial planning on the long term with (significant) sea level rise, extreme rainfall, heat and droughts, and land subsidence.

We embed our knowledge in tools such as RA2CE (Resilience Assessment and Action perspective for Critical infrastructurE), dashboards for sustainable drinking water supply and the Digital Twin for Inland shipping infrastructure. This enables stakeholders and decision makers to explore the direct and indirect effects of scenarios on infrastructure, transport and logistics. We disseminate our knowledge in scientific publications, in European and Dutch guidelines or frameworks and by promotion and sharing of the tools. We contribute to applied research networks such as the Permanent Task Group on Climate Change (PIANC) and Climate Change and Resilience (PIARC).

We focus on a network transcending approach in order to prevent (sub)optimization of networks for individual asset owners and users and maximize the resilience for society as a whole. By applying knowledge, tools and guidelines in projects with governments, industries and investment banks we aim to generate impact that results in the planning and adaptation of climate resilient infrastructure.

In 2023 we continue the developments of two key frameworks (RA2CE and Digital Twin Fairways). Cascading impacts between different infrastructure networks will be included in our resilience assessment framework RA2CE. The HORIZON Europe project MIRACA will accelerate this ambition. This project enables the step from network to system level and provides information regarding the decision making for enabling a resilient society. In the NWA Path2Zero project the digital twin will be used to explore the effects of different scenarios for zero-emission shipping on a corridor scale.

Realizing climate neutral sediment management

Sustainable and scalable sediment management of ports and waterways is crucial for the vitality and economy of deltas worldwide. Sediment management is key for the assurance of transport functions, adaptation to climate change and sustainable ecosystem quality. The main challenges for sediment management are threefold: reducing greenhouse gas emissions of dredging activities; re-use of sediments to contribute to a circular approach; scalable sediment management to adapt to climate change and sea level rise.

Climate neutral sediment management entails the reduction of greenhouse gas emissions from dredging activities and equipment. Together with Port of Rotterdam, Rijkswaterstaat and Delft University of Technology Deltares explores smarter sediment management in the Port of Rotterdam (TKI PRISMA & TKI Gel barriers). The BlueCAN project (with STOWA and Witteveen+Bos) investigates forgotten greenhouse gas emissions from small lakes and canals.

In terms of circular sediment management, Deltares focuses on the beneficial and circular sediment use, by utilizing locally available sediment in various applications, like clay for dikes, land for natural islands, land reclamations and as counteract for subsidence. Beneficial use goes hand in hand with nature-based solutions (NBS). Many activities are ongoing in the north of the Netherlands, that relate to different connected aspects of beneficial sediment re-use including clay ripening, salt marsh development, dredging sediments and the 'meegroeidijk'.

Scalable sediment management is crucial for sustainable delta management. Activities that are foreseen for 2023 are input to larger scale (coastal & riverine) sediment management under the Rethink the Delta initiative.

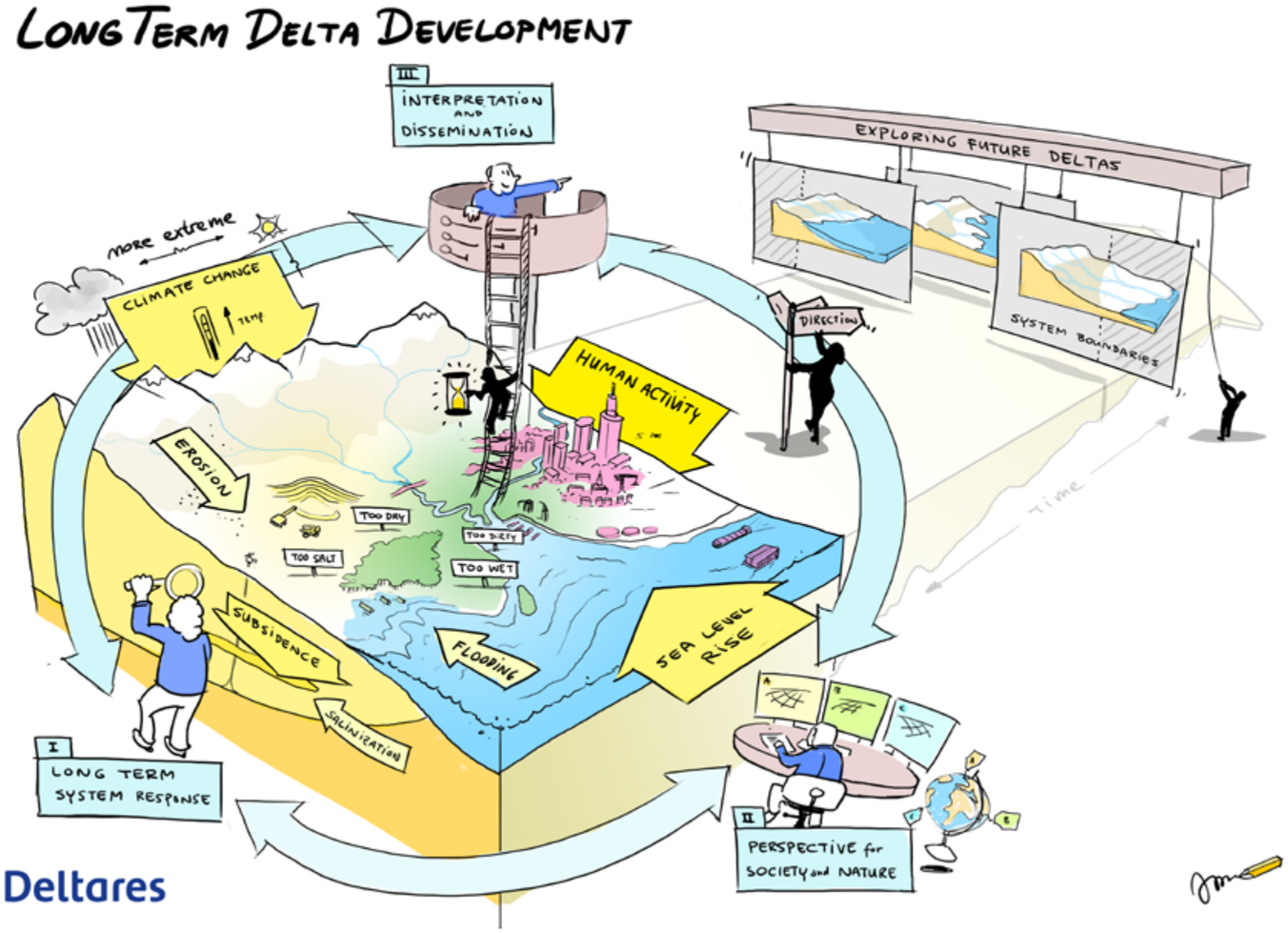
3 Mission-driven programmes and knowledge facilities

Mission-driven programmes

The research activities are executed through our mission-driven programmes and our knowledge facilities. We operate with a coordinated set of programmes with different focus that contribute to our moonshots.

- Area-based programmes provide the main building blocks (activities and outputs) for the “Deltas remain habitable” moonshot. These programmes focus on interrelated issues with specific area characteristics.
- Thematic programmes provide the main building blocks for the other moonshots (see Figure on Page 10). These are programmes relating to the major challenges facing society where we wish to accelerate progress.
- Four methodological programmes, which built around indispensable new methods and tools, facilitate transitions in areas and challenges facing society. They provide (with and through the other programmes) building blocks for all four perspectives and all moonshots.

In order to secure and develop the knowledge at Deltares and its partners, we have, in addition to the mission-driven programmes, our knowledge facilities (software & data, experimental facilities, enabling technologies, knowledge networks and alliances with universities and HBOs). Like the methodological programmes, they supply building blocks for all four perspectives and all the moonshots.



Outline of main components of the Long Term Delta Developments Programme. Source: Deltares

Long-term Delta Developments

“Long-Term Delta Developments” examines developments in water and subsurface on spatial scales of entire deltas and on time scales of 50-200 years, with the aim of mapping and interpreting the long-term development of the deltas and the consequences for humans and nature. At these scales, the complex interplay between humans, nature and climate change (such as land subsidence, sea level rise, salinization, desiccation, and flooding) will lead to major challenges to the liveability and ecological quality of many densely populated delta areas.

We identify and quantify physical changes, determine the consequences of these changes for people and nature and we focus on communication methods (storylines, visual presentations, improve data availability, etc.) to get the message across and to provide an action perspective for long-term developments that society, business and industry and governments can incorporate in their present-day choices. In addition, we strive that our knowledge, methods and tools for long-term delta developments and the consequences for people and nature will be used worldwide. The deltas we study are of significance for the Netherlands, the Deltares’ global portfolio, and vary in complexity and scope of the current level of knowledge. In this way we explore which information is important for a thorough interpretation of long-term delta developments, such that we can develop fit-for-purpose models and methods to quantify the relevant physical changes, map the consequences and offer an action perspective.

In 2023,

- we will deliver an updated Status-of-the-Delta report and an external symposium on the future state of the Dutch Delta (from a water andsubsurface perspective).
- We will give special attention to include socio-economic development and interaction with physical developments in a number of deltas such as the Nile and Ganges/Brahmaputra and make them available in a publicly accessible database.
- We will work in tool development for assessing long-term development of biodiversity in deltaic areas. Previously, research has been carried out to how certain conditions that facilitate biodiversity could change (e.g., the morphological development of inter-tidal areas, fresh-saline transition zones). In 2023 we would like to investigate how long-term (>50 years) ahead changes could be assessed.

This programme contributes mainly to Moonshot 1.

Amelander Zeegat, Photo Marco van Middelkoop

	Description
Line 1	**Interpretation and dissemination:** the knowledge and methodologies developed within this programme are used to map the long-term delta developments and the related consequences for humans and environment, given scenario uncertainties for climate change and socio-economic developments. We capture the results in useful indicators, in order to put the various consequences into perspective and to provide guidelines for which choices can be made here and now to keep the deltas liveable on the long term. In this way we contribute to national and international research agendas and facilitate the translation of scientific results into practical applications.
Line 2	**Consequences for society and environment:** the social and ecological consequences of long-term changes are described on the large spatial and temporal scale of the delta, with indicators and associated signal values describing not only physical but also socio-economic and ecological characteristics. To this end, we strive for collaboration with specialists in ecological, social and socio-economic disciplines.
Line 3	**Physical processes and scenarios:** we use the core expertise of Deltares to improve, develop and combine models, methods, tools and data that map the long-term changes in causes (climate, human activities) and consequences from a physical, ecological and socio-economic perspective. We focus on areas that are relevant for the interpretation and definition of indicators for a number of selected deltas.

Partner type	Partner	Description of the cooperation
Dutch Government	IenW, RWS*	Marco_van_Middelkoop_Amelander_Zeegat, track 2. The intent is to better line up KP-ZSS spoor 2 and our programme.
	EZK, Dutch Embassies, Egypte and Vietnam	EZK: future development Wadden. Sharing our delta storylines via the water envoys
Knowledge partners	IHE, TUD, UU, WUR, Delta Alliance, USGS	• IHE: joined improvements on coastline tools (ShorelineS, G-SMIC, Mangrove coasts) • TUD: long term development estuarine systems (mainly Wadden), surface water salinization and Rivers2Morrow • UU: groundwater (including salinization coastal zone), surface water (PCRGLOBWB / GLOB-GM (ERC Bierkens)), subsidence and Rivers2Morrow • USGS: long-term groundwater: droughts, salinization, tool development; plans for collaboration on flooding and morphology.
International government and organizations	Global Commission on Adaptation	Join the International Knowledge Panel on Deltas and Coastal Areas (IPDC)
Private sector	VEI, Arcadis	Collaboration in e.g., RVO projects on freshwater availability in subsiding deltas under long-term human and climate change presses.

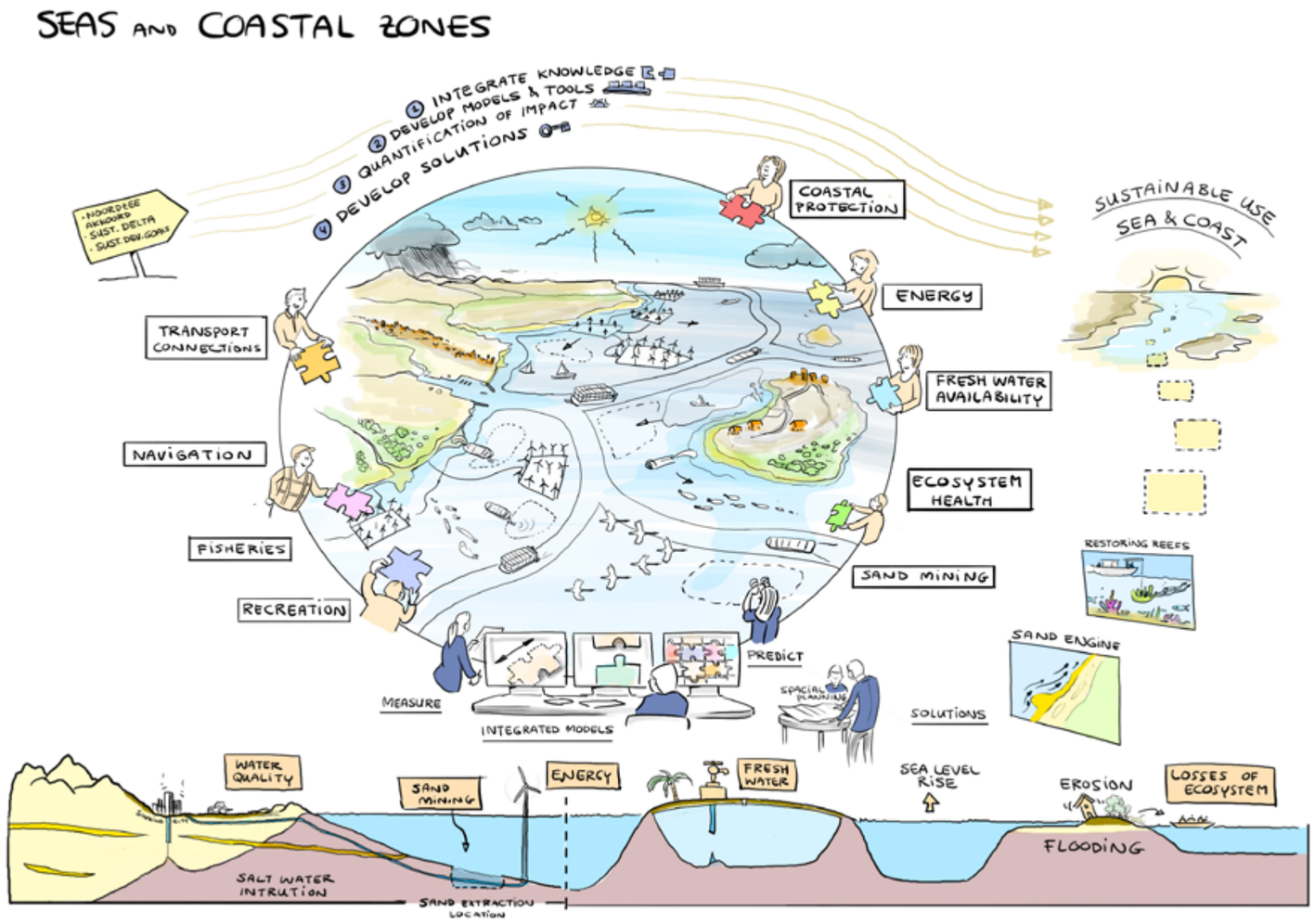
* Abbreviations and translations are provided in Appendix B

Seas and Coastal Zones

Seas, and for the Netherlands specifically the North Sea, are important for food supply, energy transition, sand extraction, transport by water and recreation. The coastal areas (land), which strongly interact with the marine system, are of great economic, ecological and societal importance (e.g., providing drinking water). Both at sea and in the (often narrow) coastal zones (land), the user functions impact each other and there is a growing need for integral knowledge and tools to optimally combine the various functions.

This programme focuses specifically on the development and application of in-depth and integral (system) knowledge and instruments on the basis of which stakeholders can make choices about the future design, use and management of seas and coastal areas. In addition to the development of fundamental process knowledge, data, and model tools, focus areas are also needed to be able to test applications, in collaboration with relevant stakeholders. That is why two specific areas are highlighted: the North Sea case, in the context of the North Sea Agreement, and the coastal zone of small islands (Small Island Developing States, SIDS), as a testing ground for the effects of overexploitation (groundwater), climate change and socio-economic pressures in confined space.

The integration of system knowledge focuses on combining data and knowledge of different coastal and marine subsystems and processes with the focus on integrating morphological coastal (change), hydro (geo)logical soil conditions, floods and groundwater quality.



Outline of the main components and research lines of the Seas and Coastal Areas programme. Source: Deltares

The tool development focuses on:

1. remote sensing (EO) techniques
2. integrated modelling of water, soil and subsurface, and
3. multidisciplinary information systems, such as community models and decision support tools.

The developed knowledge and tools are applied to develop innovative integrated solutions for current and future threats for the design and management of a sustainable, resilient and liveable sea and coast.

In 2023, the emphasis of the programme activities will be on the application of newly developed (impact) tools to aid planning and impact assessments and designing of conceptual solutions. Newly developed integrated model environment will be delivered with some appealing integrated (demo) applications (flood, groundwater and coastal morphology). In addition, using the North Sea model, the effects of future use of space around the various functions are determined in consultation with stakeholders. The global assessments of hazards and possible solutions for SIDS countries are also shared with local stakeholders, with a view to other coastal areas in the world.

This programme contributes to Moonshots 1 and 2.

Coastal protection on a small island (photo: Alessio Giardino)

	Description
Line 1	**Knowledge integration** focused on the 'transport paths' between coastal zone and sea for raw materials (e.g., groundwater (drinking water and salinisation) and sediment) and polluters (e.g., nutrients).
Line 2	**Integrating geo-hydro-eco-morphological knowledge into instruments** that support the sustainable design, use and management of seas and coasts. This includes process-based and Community models (hydro, eco, morpho, waq, infra), and tools for optimal MSP and ICZM, with the North Sea as a testing ground.
Line 3	**Quantifying the consequences of existing and future trends** (climate and socio-economic changes) on the liveability of coastal zones, using models, EO, and impact tools, with SIDS countries as a testing ground.
Line 4	**Development of integral conceptual solutions for a future-proof design** of marine and coastal zones worldwide and with SIDS and North Sea as a testing ground. This includes the use of green, gray and hybrid solutions, including the development of solutions in the limited space. Models, decision support tools combined with remote sensing (line 2) are used as a design tool.

Partner type	Partner	Description of the cooperation
Dutch Government	RWS	Dutch Coastline Challenge: sustainable maintenance and nourishment strategies for the North Holland coast.
Knowledge partners	UT TUD, Leiden, NIOZ, HZ, Horizon Europe, WUR, VU, GNS (NZ)	SeaCode, Melody, DuneForce, C-SCAPE, DOORS, United, Jerico, FutureMARES, CoCliCo, COASTMOVE, Integrated modelling on SIDS, applying our modelling framework.
International government and organizations	Marshall Islands government, World Bank, Asian Development Bank, ESA, SPC	Majuro CVA (Coastal Vulnerability Assessment) project, Co-development of short-term and long-term adaptation options (through adaptation pathways) for SIDS countries, EOatSee (Earth Observation data for global modelling of hazards resulting from coastal erosion and SLR), collaboration on applying modelling framework on Pacific Ocean SIDS.
Private sector	Marine sector	SeaCode, ShoreLines

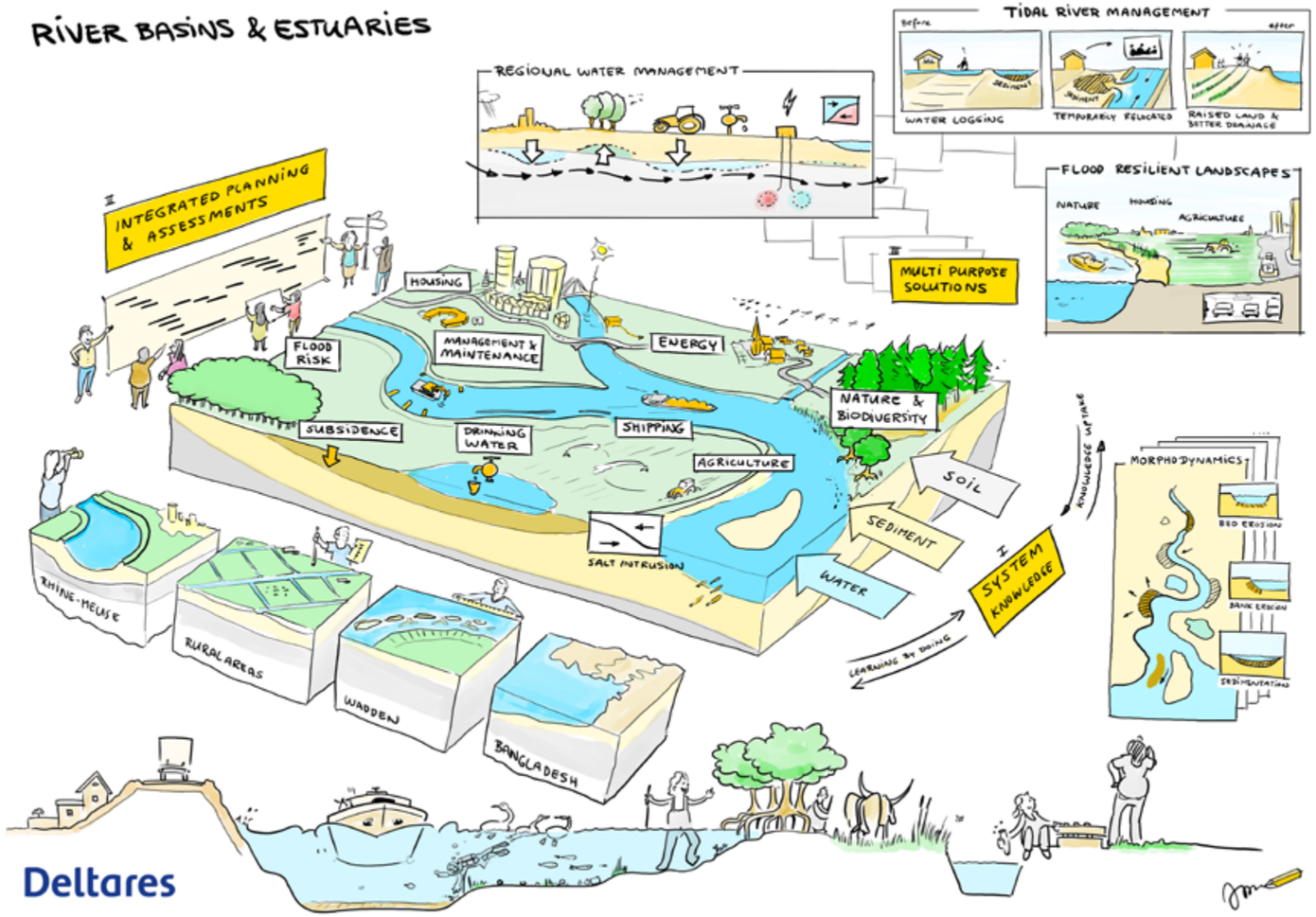
River Basins and Estuaries

As an area-based programme, River Basins and Estuaries focuses on specific areas: a river basin estuary, tidal basin, lake or rural area, in which multiple land uses and challenges are combined. The main objective of this programme is to develop integrated, resilient and future-proof design and management concepts for river basins, estuaries, tidal basins, lakes and rural areas. The main objective can be divided into four interlinked objectives:

1. Increase and apply knowledge on the functioning and response of the (a)biotic system.
2. Develop strategies and integrated methodologies to assess resilience, system services and solutions.
3. Develop (multiple) solutions to tackle societal challenges.
4. Develop, improve and apply knowledge and tools (data, models, tools, instruments)

These are preferably applied to the selected case areas as defined for this programme: Resilient Rivers (regulated & dynamic), Rural Areas, Estuaries & Lakes (Wadden, ZW Delta, IJsselmeer).

In 2023, we will promote the concept of “Water and subsurface” (Water en bodem sturend) and the research products underpinning it, in projects on making the soil and water system a more integral part of spatial planning.



Outline of main components of the program on Long-term Delta developments. Source: Deltares

In 2023 and further on, we invest in projects using the GOW (area oriented & societal challenge oriented) approach. We focus on specific areas in case areas, where multiple challenges at the same time are or importance and that will be addressed together with multiple actors in and related to the area. Here the programme lines 2-3 become more and more important. To reach impact, we have broadened the case studies, as we are looking more to typologies of systems, instead of putting certain case areas in the spotlight.

Windmills at Kinderdijk

	Description
Line 1	**Knowledge on integrated system behaviour:** The development of knowledge on integrated system behaviour and interaction of processes. It deals with application of this knowledge in case areas and making the knowledge (and data) available for application in other projects, by embedding in models and tools. Models can be numerical models and conceptual models, that describe our current understanding of the system functioning. System knowledge is required for the generation and selection of possible solutions and transitions, estimating system effects, and for making well-founded decisions.
Line 2	**Integrated planning and assessments incl. resilience and governance** focuses on developing methods for integrated assessments. This includes methods for the quantification of the resilience of river basins and estuaries in relation to the many challenges that are faced in these areas. In the development of the frameworks, we also include the social and ecological values as well as other aspects relevant for substantive decision-making processes.
Line 3	**Smart, multiple solutions and combining solutions** is about identifying solutions that serve multiple purposes with a joint optimal effect (which can be suboptimal for single purposes): “From trade-offs to benefits”. One can think of nature-based solutions that decrease flood risk, but also offer opportunities for nature and recreation. Other examples are solutions that contribute to increasing employment, mitigate biodiversity loss, inclusiveness, reducing poverty, or other socio-economic aspects.

Partner type	Partner	Description of the cooperation
Dutch Government	IenW	EU projects (PREPSOIL) Water and subsurface driving spatial planning
	RWS	integrated river (basin) management+ EU projects (Merlin, PREPSOIL)
	LNV	Nationaal Programma Landelijk Gebied (NPLG)
	Regional governments + BZK	GOW approach (NOVI, NOVEX)
Knowledge partners	Hogescholen (SAXION, HZeeland)	SPRONG requests for proposals
	TUD	NWO & research projects
	WUR	Rural areas, estuaries & lakes
	EU universities	EU R&I projects
International government and organizations	EU	Research projects
	International River basin management commissions	Integrated river basin management
Other (NGO, IFIs, citizens)	Nature organisations	Especially case study estuaries & lakes

Resilient Cities

More than half of the global population already lives in cities. Cities continue to expand, and new cities are created. They are appealing but they are also vulnerable to climate change, earthquakes, subsidence, floods, and epidemics, and they must have the capacity to anticipate, cope with, resist and recover from these events and pressures.

Deltares' knowledge of water, subsurface and infrastructure is crucial for urban design, planning and management. We are always searching for new solutions and we develop software that is applied worldwide in the urban setting. We measure, monitor, analyse and model urban issues in order to work with our urban partners on integrated solutions for resilient and liveable cities.

The main objective of Resilient Cities is to develop information, tools and perspectives for actions that contribute to an integrated solution of the problems that cities around the world face as a result of climate change, natural disasters, sea level rise and land subsidence and that strengthen the resilience of cities by making them safer, healthier, more attractive, more productive and more sustainable. In 2023 our subobjectives are the:

- Development of an action perspective that can be used in (cost) efficient approach (planning and realization) to increase the resilience of cities. This should take into account other urban challenges such as climate adaptation and energy transition, in combination with improving quality of life, accessibility and healthy urbanisation
- Knowledge development about the actual quantitative effectiveness of measures aimed at making cities more climate-proof and increasing the recovery capacity after disasters.
- Developing resources (tools, methods, etc.) for cities to realize the necessary measures in combination with the other urban tasks (energy transition, densification, accessibility, quality of life)
- More frequent use of the Deltares urban toolbox (analysis methods, software tools, data exchange protocols) for reducing water and subsurface related problems and increasing the resilience of the city.

In 2023, based on several projects around the theme "Water en Bodem Sturend" (Water and subsurface driving policy), new activities are programmed for 2023. The output of the projects will provide knowledge on flood risk zoning in urban settings and flooding due to interaction between urban and regional water systems. This knowledge can be used to determine suitable housing locations and reduce flood risks in urban areas.

North Miami Beach

	Description
Line 1	**System analysis and understanding:** Generating and transferring insight into the functioning of the urban water and underground system, including (underground) infrastructure. Understanding relationships between water and subsurface and all other physical elements (infrastructure, buildings, energy), ecology, socio-economic aspects and human health: the urban system as a whole.
Line 2	**Create, measure and monitor measures:** Gaining insight into the effectiveness of measures for improving and creating resilience through the urban water and subsurface system by using physical experimental space in the city (living labs); collecting quantitative data on the effectiveness of measures, and qualitative and quantitative analysis of effects on human health.
Line 3	**Planning, realization and asset management:** Developing methods and tools to take the step from design to realization and management of measures for a resilient urban environment. The implementation must be geared to other urban tasks such as energy transition, construction task, etc.
Line 4	**Software development:** Tool development and maintenance for system understanding, measures assessment, implementation and policy and management. This line is supporting the other lines.
Line 5	**Subsidence:** focusses on the built environment related to for example damages and impacts of subsidence in cities and on buildings and infrastructure is part of Resilient Cities.

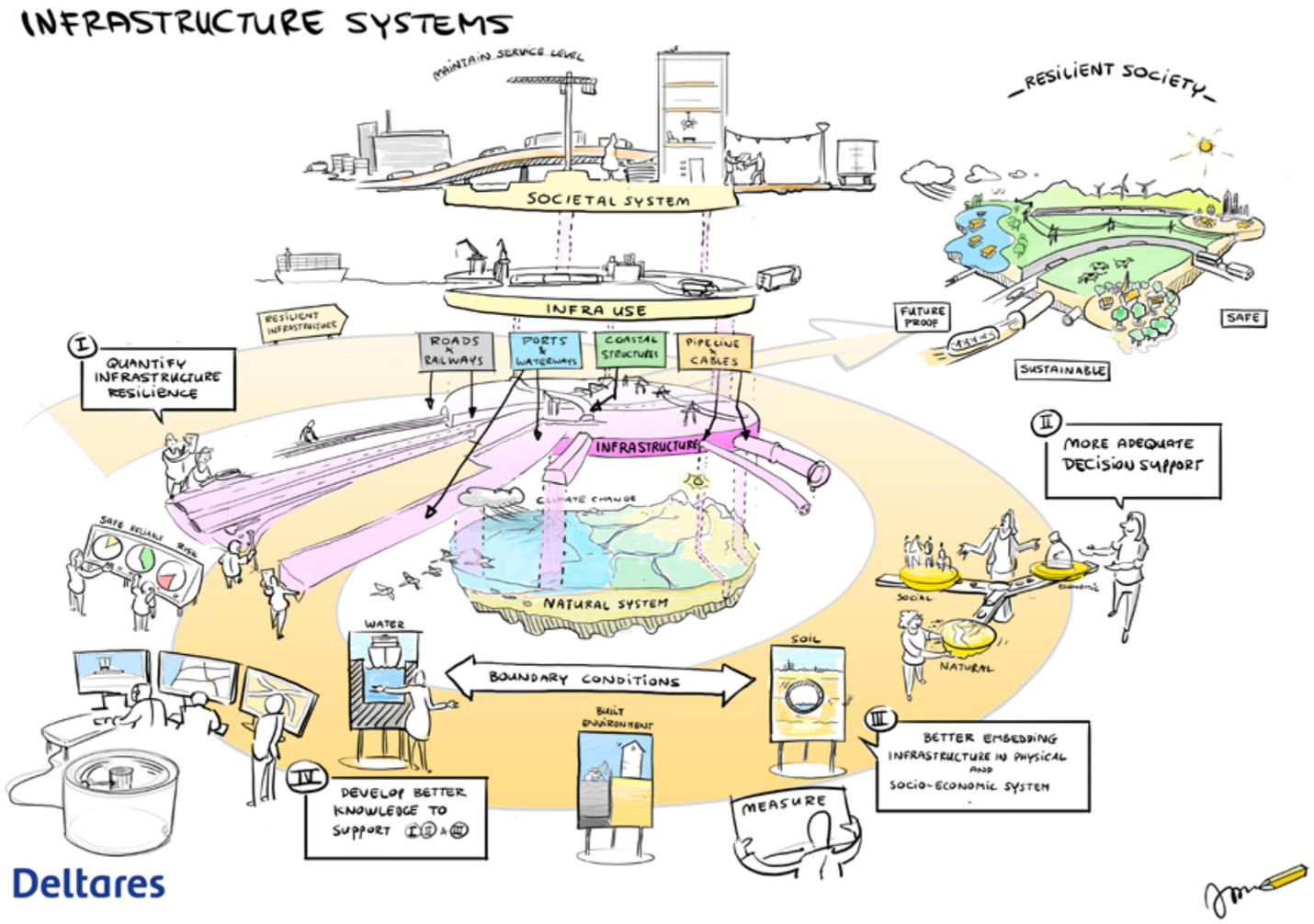
Partner type	Partner	Description of the cooperation
Dutch Government	RWS-WVL, DPRA, STOWA, consultancy firms, WUR, TUD	Knowledge development for IenW (more specific, the Deltaprogramma Ruimtelijke Adaptatie) is supported by the programme through yearly activities for the programme NKWK Klimaat Bestendige Stad. This programme delivers a part of the applied knowledge that supports National guidelines of the Dutch Delta Program.
	Municipalities and Waterboards	Cooperation in TKI projects in which the D-HYDRO Urban model instruments are tested and further developed
Knowledge partners	UU, TUD, WUR, Hanze Hogeschool	Setting up a map server that can be used to study the resilience of cities worldwide; setting up an NWA programme that focuses on method development for risk analyses by the financial sector; Guide for realisation of drought resistant urban green space; Fact finding about the performance of rainwater infiltration measures by means of creating, monitoring and analysing
International government and organizations	VU-IVM, Ecologic, NGI, CMCC, Technalia, RCN, C40	EU project developing a climate stress test based on globally available data; development of software for sizing grey-green drainage systems
Private sector	Various Dutch consultants	Cooperation in TKI projects for development of D-HYDRO

Infrastructure Systems

The objective of Infrastructure Systems is to quantify and optimize the resilience of line infrastructure systems to offer the desired service level to society now and in the future, with optimal embedding of this infrastructure in the physical and socio-economic system.

This programme focuses on ports (incl. breakwaters and sediment management), waterways, roads, railways, cables and pipelines. A key aim is to embed the infrastructure optimally in the complex (physical) soil and water system as well as in the built environment. To this end, we look at the design, implementation, operation and maintenance of (line) infrastructure with respect reliability, safety and sustainability. Another key objective is to keep the (line) infrastructure resilient under (changing) normal and extreme conditions, now and in the future. We look at the impact of external changes on the (service level of the) infrastructure, such as climate change as well as socio-economic and technological developments.

The programme focuses primarily on the infrastructure itself and usage of the infrastructure by society (the two middle layers in the figure) and embedding the infrastructure in the water and soil system (bottom layer) and the societal system (top layer). Society is benefitting from infrastructure by the services it offers to users. At the same time, construction and maintenance of the infrastructure come with significant costs, both in terms of direct investments and in terms of negative effects for individuals (“not in my backyard”) and nature. These costs and benefits need to be balanced: the service or ambition level for the functioning of the transport infrastructure need to be aligned with the stakes of different stakeholders, the changing demands from society and the changing conditions in the natural system. Therefore,



Outline of the main components of the program Infrastructure systems. Source: Deltares

the programme aims to develop knowledge and tools to provide the governments, asset owners and other stakeholders with the action perspectives to ensure that the transport system has the right level of resilience to remain serving society.

In 2023, we will pursue the following new activities:

- Effects of climate change on soil-structure interaction, especially the effect of heat stress and heat interaction.
- Water- and soil-based spatial planning for asset management purposes in combination with adaptation to extreme weather, and for spatial planning in view of climate change.
- Carbon reduction of asset management.
- Nautical safety assessments in the busy North Sea using data science on AIS data, digital twin technology and hybrid modelling.

In 2023, we foresee several experiments in the physical facilities such as the Hydro hall on ports/transport infrastructure, the Water soil flume & biochemical lab on alternative dredging methods to reduce costs and emissions, and the Geo Centrifuge on the behavior of soil-structure interaction in the case of pile foundations and sewer systems.

Roadways and waterways in the Netherlands

	Description
Line 1	**Define and quantify the resilience of infrastructure networks and systems** focuses on developing knowledge, frameworks and tools to quantify the impacts of external changes/ hazards on infrastructure systems. We account for both direct damage to the infrastructure and indirect damage and cascade effects for its users. We explicitly pay attention to future changes to obtain insight into the present and future resilient level of the infrastructure.
Line 2	**Adequate information for action perspectives and decision making for planning resilient infrastructure systems** focuses on developing methods and approaches to identify and evaluate measures to maintain or increase the resilience of infrastructure systems (with respect to the desired ambition level).
Line 3	**Optimize the design, embedding, maintenance and usage of line infrastructure in its physical and socio-economic environment** focuses on embedding, implementing, maintaining and usage of line infrastructure in its physical and socio-economic environment with the focus on reliability, life cycle costs and benefits and sustainability. This can entail both the design and implementation of new (line) infrastructure as well as modifications to existing infrastructure.
Line 4	**Maintain and increase the physical knowledge base of infrastructure systems** focuses on maintaining and strengthening the (physical) knowledge base of the infrastructure, and the interaction with the water/soil system and the built environment.

Partner type	Partner	Description of the cooperation
Dutch Government	RWS, IenW-DGWB	Climate resilient networks, Horizon Europe
	ProRail, Waterboards, Municipalities	Europe Rail, RESET, STEM, H2020 In2Zone, Cooperation SSWN
Knowledge partners	TUD, TU/e EUR, TNO, MARIN, KWR KIM, VU, KNMI	MSc & PhD supervision, TISCA project, Cooperation SmartPort, various NWO en TKI projects, Horizon Europe project MIRACA
International government and organizations	Worldbank Asian Development Bank	Technical assistance
Private sector	Next Generation Infrastructures, Energy companies, Water utilities, Port operators, Contractors, Engineering consultants	TKI projects: TKI Schroefstralen, TKI PRISMA, TKI Gel barriers, TKI trenchless technology
Other (NGO, IFIs, citizens)	CROW, COB, NEN, ISO, PIANC, PIARC, CEDA, SmartPort, NSTT	SmartPort cooperation agreement & secondment Participation to PIANC, CEDA, PIARC, CROW, NEN-ISO working groups, Rock Manual

Infrastructure Renewal and Renovation

Physical infrastructure is vital for a society. As in many countries, much of this infrastructure in the Netherlands was built in the 20th century. Since then, the quality of the infrastructure required to keep our country safe, accessible and habitable has been maintained by means of intensive management and maintenance.

In the coming decades, the burden and demands on infrastructure networks, particularly in delta areas such as the Netherlands, are expected to change dramatically. Nevertheless, existing components in the current infrastructure constitute an excellent basis for ongoing construction (even in uncertain future scenarios).

However, long-term exposure to degradation has rendered components outdated. As a result, the parts with the longest lifespan will soon be reaching the end of their service life. Moreover, the networks are being used ever more intensively and are already being affected by developments in the fields of climate, sustainability, and ICT. This means that simply maintaining the current quality level will require extra effort from managing authorities.

To make a well-considered and substantiated decision as an asset manager about replacing, or extending the life span of, infrastructure, it is important to have the right information about the current condition of the infrastructure and the risks involved in different decisions.

These decisions involve major implications because they represent an opportunity to initiate desirable changes in the network (with a view to future developments).

The aim of this programme is to provide support for managers during their decisions about renewal and renovation of infrastructure as part of a strategy on the road to a future-resilient network. To make the task manageable by using both actual and/or state-of-the-art civil-engineering knowledge as an assessment framework. Although the emphasis here is on structures in the water infrastructure – in other words, hydraulic structures, quay walls, other types of retaining walls and the associated components - the assessment framework must also be applicable to decision-making for other infrastructural components.

Maeslantkering

	Description
Line 1	**Technical Lifespan (TL) of infrastructure** is about capturing and maintaining the knowledge base, as well as the knowledge about various relevant load conditions and degradation processes and their effect on the condition of ageing structures in the water infrastructure. We develop advanced techniques, tools and methods for (1) mapping the current condition (2) translating data to information to support decision-making and (3) deriving degradation functions to determine the residual life of ageing structure.
Line 2	**Functional Lifespan (FL) of infrastructure** is directly related to the performance of its components (e.g., hydraulic structures) in the various networks that together form the water system. External developments and different use can lead to changes in their performance and lead to the end of functional life. We develop relevant techniques, tools and knowledge to simulate and quantify the performance of the (water) infrastructure.
Line 3	**Assessment framework incl. Economic Lifespan (EL) of infrastructure** contributes to an integrated assessment framework with which an asset manager can compare the future-proofness of various options. And, thereby, support the decision-makers in their prioritization and planning of renewal and renovation measures.

Partner type	Partner	Concise description of the cooperation (objectives and way of working)
Dutch Government	IenW, RWS and the waterboards	This programme has strategic partnerships with the Ministry of Infrastructure and Water Management (asset owner), Rijkswaterstaat (asset manager) and the waterboards (asset owner/manager) on future proof water infrastructure
Knowledge partners	TNO MARIN	The knowledge and expertise of and MARIN play a vital role decision support on hydraulic structures. Within the knowledge programme Natte Kunstwerken there is an intensive co-creation with TNO and Marin.
International government and organizations	I-STORM, PIANC	Cooperation in network organizations.
Private sector	Contractors, engineering consultants	Private partners are the service providers that support water managers in implementing renewal and renovation managers. Their knowledge and expertise is vital for joint initiatives.

Flood Defences

To maintain the Netherlands habitable, flood protection measures such as dikes, dams, dunes and storm surge barriers are crucial. Due to climate change, land subsidence, increase of population and economical values, large investments with large spatial and social impact are needed in the Netherlands and other countries to protect against flooding. The programme ‘flood defences’ focuses on this social task. The programme ‘flood defences’ contributes to the overarching Mission F of the Dutch Government. Within this research programme, knowledge, methodologies and tools will be developed to improve the insight in failure probabilities (and therefore flood risk) of flood defences and to be able to develop and assess flood defence reinforcements essential to realise the desired flood safety standards meeting other criteria related to (maintenance) costs and social and spatial impacts. Key are our unique research facilities (software, field measurements and laboratories) such as the wave flumes and basins, Geo Centrifuge and other geotechnical laboratories) and our national and international networks.

Besides focus and in-depth research, the programme also looks in a broader perspective using the concept of waterveiligheidslandschappen (flood safety landscapes) by exploring nature-based solutions, and including spatial and societal challenges such as housing, spatial planning and energy. In addition, the flood defences, the flood defence zone and the wider environment in the foreland and hinterland can contribute to sustainability objectives and environmental quality.

In addition to the activities initiated in 2022, the programme will have an additional focus on structures which function as flood defences and will start the planning of the Floodrisk2024 conference together with our international partners.

Reinforcements of the Afsluitdijk (photo: Jan Wessels, beeldbank.rws.nl)

	Description
Line 1	**Understanding failure of flood defences.** Development and quantification of failure pathways and failure mechanisms leading to flooding.
Line 2	**Design of (reinforcement of) flood defences** Strengthening and optimizing the toolbox for design and execution of reinforcements of flood defences to meet criteria related to budget, planning, societal impact and sustainability.
Line 3	**Strengthening research infrastructure (software, lab, networks)** Strengthening the specific research infrastructures related to flood defences such as software (e.g.,artificial intelligence, emerging technologies, CFD modelling), experimental facilities (laboratories and field) and knowledge networks.
Line 4	**Integration with societal context (“waterveiligheidslandschappen”)** Integration of technical expertise of flood defences with societal context such as risk-based approach, sustainability, biodiversity, spatial quality and long-term adaptation strategies.

Partner type	Partner	Description of the cooperation
Dutch Government	IenW, RWS-WVL, Kennis voor Keringen en BOI HWBP, Waterboards	Contributions to the evaluation of the ‘waterwet’ Contributions to the approach for cost assessments as part of the new levee assessment cycle.
Knowledge partners	TUD, WUR, UU, RUG, HR Wallingford en EA (UK), INRAE (FR), USACE (USA),	Knowledge programmes, exchange and hosting of students.
International government and organizations	ISSMGE, ICOLD, FloodRisk2024	Collaboration via committees and networks of the international societies for geotechnics (ISSMGE), Dams (ICOLD) and flood risk (FloodRisk2024).
Private sector	Engineering consultants, The Taskforce Deltatechnology	

Water Resources

Water Resources deals with water security, the availability of fresh water in a changing world. The programme is committed to reducing problems of water scarcity and drought and finding sustainable solutions for future water availability under climate change and socio-economic developments. The programme contributes to water security at various levels; catchments, national and regional scale, this concerns both surface water and water in the subsurface.

According to the principles of integrated water management (IWRM) the programme develops knowledge, methodologies and tools for quantifying water security; the water availability in the physical system, (consequences of) water shortages for different users and society, and proposals for solutions that are climate resilient, economically resilient, environmentally responsible, and social inclusive.

The programme enables the analysis and understanding of good water management to support planning and decision-making. Therefore, the water system is approached and analysed from a broad, integrated water security perspective, including the relations with food security, energy security and social stability. Since climate-resilient water security is not limited to technical solutions for water scarcity, the interdisciplinary connection with other programmes and organizations that have complementary knowledge, for example of biodiversity, energy security and social inclusiveness, will be strengthened in order to maximize the societal impact of Deltares.

The programme ambitions are:

- As a nationally and internationally renowned institute, Deltares contributes to the (scientific) world by increasing stakeholders' awareness and knowledge of problems related to water resources and water use in a changing world. In co-design with the stakeholders, we provide better insight and contribute to integrated solutions in order to reduce risks in river basins and countries and regions worldwide
- In collaboration with international organizations, governments and NGO's, Deltares is committed to the design, planning and implementation of resilient and sustainable water management, by developing water-related services and integrated solutions that address multiple risks, such as water security, migration and climate change. Therefore, Deltares also contributes to business models that increase the chance of investing in poor, vulnerable and conflict situations, and that contribute to societal adaptivity and inclusiveness
- Deltares contributes to setting the political and public agenda in the field of drought and water scarcity, with emphasis on enabling solutions that transcend domains (e.g., droughts and flooding), sectors (e.g., relations with the agricultural and energy transition) and borders (e.g., cross-border solutions in the Rhine and Meuse basin), aiming at the transition to future sustainable water systems and water sharing (ref. MMIP Agriculture, water and food, sustainable; development of rural and urban areas).

In 2023, the programme will place more emphasis on stakeholder participation as well as the elaboration of Moonshot 3 in specific pilot areas, such as the Rhine catchment, and in larger projects. We will adopt and continue to support the developments and approach of BlueEarth by developing prototypes and applying them in pilot areas, especially in river basin planning contexts and in humanitarian aid and responses context. The start of Stars4Water and Action on the Ground initiative will provide good opportunities for this.

	Description
Line 1	**Improving understanding of stakeholders on multiple risks and challenges concerning water availability** aims to raise awareness and understanding on impact of multiple risks such as climate change impacts, drought, water scarcity, insecurity and migration on the water availability. The programme is committed to catalyze action for water supply and drought management planning. We explore improvements in monitoring data on the ground or new data science technologies in relation to SDG's, Sendai or the national adaptation plan. Together with our stakeholders we produce data to identify risks based on integrated system analysis and we support decision making in order to deal with challenges and threats.
Line 2	**Supporting river basin organizations and water users in transition in water allocation regimes** aims to contribute to the design, planning and implementation of transitions in water allocation regimes towards climate resilient, sustainable, equitable and economically efficient sharing of water resources including necessary cross-sectoral, cross-national and cross-domain coordination. Together with our strategic partners (TNO, WUR, IHE, Wetlands International, IenW, GIZ, etc.) we enable strategy building around water, food, energy and environmental security contributing to peace and stability in developing countries and support policy making in the Netherlands for making necessary transitions.
Line 3	**Providing knowledge to governments, NGO's that address climate-related water risks in fragile and conflict situations** supports the implementation of resilient and sustainable water resources management, water related services and integrated solutions that address multiple water-related risks and based on business models that attract investment in poor, fragile and conflict contexts, while promoting socially inclusive services for both refugees and host communities. We provide technical support of water resource management and disaster preparedness plans and actions, as well as in the site selection for accommodating new refugees and forcibly displaced people.

Partner type	Partner	Concise description of the cooperation (objectives and way of working)
Dutch government	IenW, BuZa, RWS, PBL, KNMI, RVO, LNV, water boards, provinces, drinking water associations	Collaboration within projects
Knowledge partners	UU, WUR, VU, KWR, UT, TUD, TNO, EU	Collaboration in strategic and fundamental research
International government and organizations	AGWA, UN, WMO	Collaboration within projects
Private sector	Consultants and engineering firms	Cooperation in projects and TKI-proposals
Other (NGO, IFIs, citizens)	WB, ADB, AFDB, Green Climate Fund	Collaboration within projects

Natural Hazards

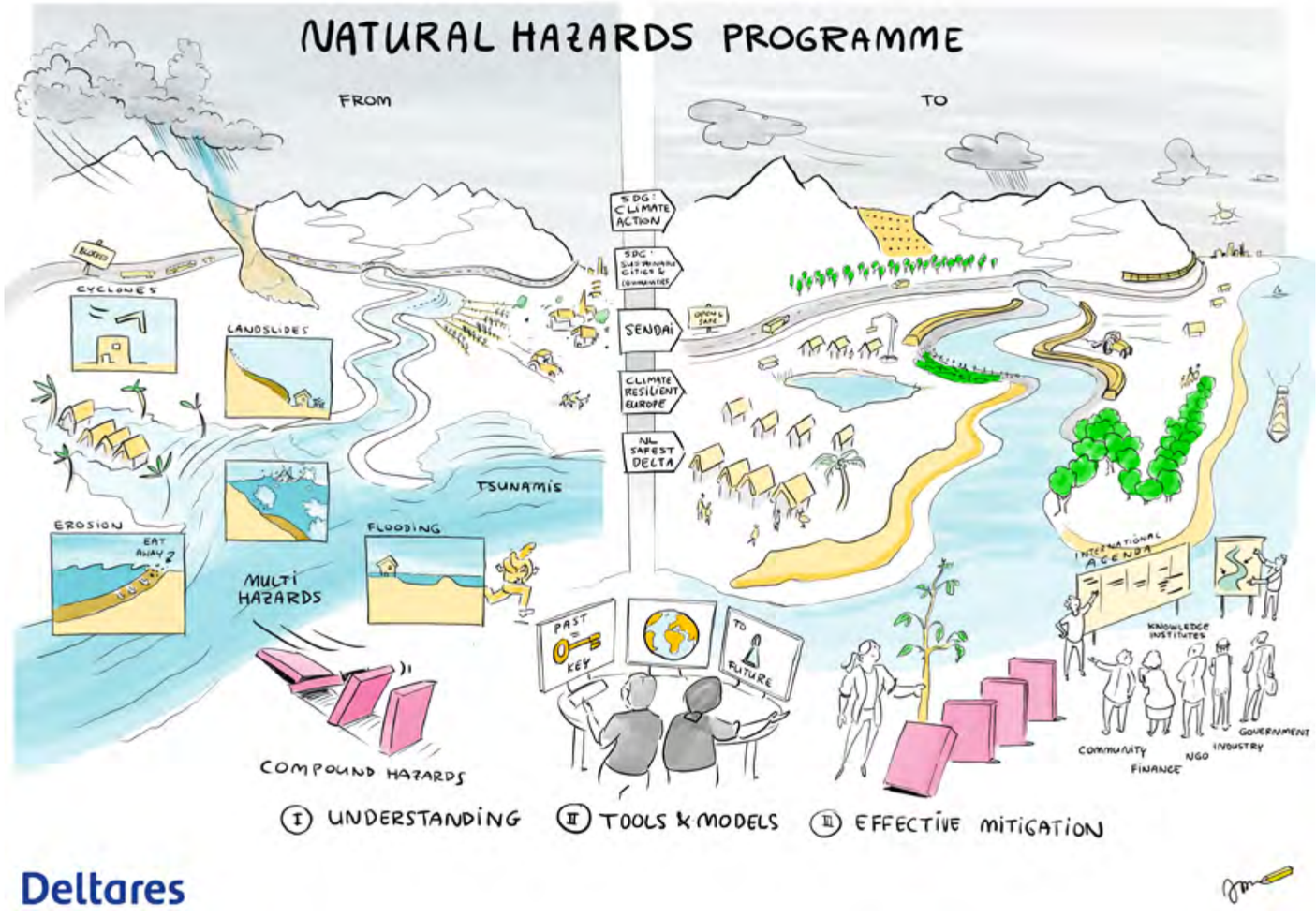
Every year, natural hazards resulting from extreme events kill approximately 90,000 people and affect close to 160 million people worldwide. With climate change, population growth and increasing areas of human habitation, this number is expected to increase in the coming decades (WRI, 2020).

The “Natural Hazards” research programme aims to help reduce the negative consequences of extreme (compound) events worldwide. We do this through:

1. Innovative research on the sources and pathways of (compound) natural hazards;
2. The provision of data and the development of models and tools to quantify future natural hazards; and
3. The development of methodologies to quantify the effectiveness of physical DRR-measures.

Within the Dutch context, research in this programme primarily focusses on understanding, quantifying, and measures to prevent (or mitigate) marine, fluvial and pluvial flooding and event-driven erosion to ensure that the Netherlands remains in the world’s safest delta coming century.

Internationally, we address flooding, event-driven erosion, landslide and wind compound hazards resulting from extreme meteorological and geological events such as tropical cyclones and tsunamis, alongside locally-appropriate (feasible, effective and acceptable) physical measures to mitigate these hazards (source and pathway) supporting the Sendai Framework and the SDG targets. The programme supports Moonshot 2 and has strong collaborative research links with Deltares Research Programmes *Risk Analysis*



Outline of main components of the programme on Natural Hazards. Source: Deltares

Flooding in Thailand

and Management (methodologies for impact assessment of natural hazards), *Real-time Information* (impact-based forecasting), *Flood defences* (hazard prevention measures), and the five *Gebiedsopgave* programmes (prediction of current and future hazards).

In 2023, we foresee continued research and development around (compound) marine, fluvial and pluvial flooding, event-driven erosion and landslides. We will continue these efforts within the conceptual framework of GHIRAF, supporting a consistent approach for hazard risk and impact assessment. We support research leading to improved and faster flood and erosion models.

We continue collaboration with partners like NCKU (National Cheng Kun University, Taiwan) and SWCB (Soil and Water Conservation Bureau, Taiwan) on enhancing knowledge for automatic detection of landslides via earth observation, susceptibility and hazard, and influencing area, the University of Salerno, looking at the effects of landslides on protection structures; USGS, on event-driven flooding and erosion on sandy and reef-lined coasts; and universities in the Netherlands, UK, USA and Australia on improving physics in key hazard assessment models.

	Description
Line 1	**Better understanding:** Improve knowledge base and statistical description of the sources and pathways of single, compound and consecutive natural hazards
Line 2	**Improved prediction and quantification:** Improved use of new data sources and development of tools and models for the quantification of (compound) natural hazards following the GHIRAF philosophy.
Line 3	**Effective mitigation**: Evaluation and quantification of the effectiveness of (grey and green) adaptation measures that help to reduce the impact of extreme natural hazards

Partner Type	Partner	Description of the cooperation
Dutch Government	RWS- WVL	Collaboration within KPP programmes: 1. Development of GRADE, contributions to the KNMI'23 scenarios and EU floods directive 2. Riverine research: Improvement of modelling concepts, morphological and hydraulic research in the Dutch rivers. 3. BOI Hydraulic Loads: Research on extreme wave conditions and storm surge for the North Sea based on wind statistics and downscaled weather simulations. 4. BOI Dunes: Development of an instrument to verify the effectiveness of Nature-Based coastal protection solutions against flooding. 5. Kennis voor Keringen: Development of knowledge on event-driven erosion for use in the safety assessment of sandy and hybrid coastal defences.
Dutch government	PBL	International networking + contribution to the Future Water Challenges 2 project through the blue book and the Digital Delta.
Knowledge partners	KNMI, UK MetOffice, Universities: WUR, UT, TUD, VU, Delaware, Auckland, Plymouth, Bath, CMCC, NCKU, Salerno	• KNMI – development of the KNMI'23 discharge scenarios, improvement of GRADE • WorldBank projects in a.o. Mozambique, ongoing initiatives on Impact-Based forecasting • Supervision of PhD and MSc students • Collaboration in H2020 EUCP, CLIMAAX, ESA-EOatSEE • Development of a numerical model based on Material Point Method to describe the landslide runout • Impact forces on retaining structures caused by fast debris flow. Effect of rigid vs flexible structures.
International government and organizations	USGS Soil-Water Conservation Bureau	Joint development and testing of new models (SFINCS, HurryWave) and meta-models (BEWARE, SIERN). Development of system knowledge. Collaboration to determine the landslide susceptibility and hazard map for an area in Taiwan.
Private sector	Arcadis	Joint development of event-driven erosion model XBeach for application in the Netherlands
Other (NGO, IFIs, citizens)	Global Flood Partnership	International network with large organizations like (NASA, JRC, WFP, RedCross etc) all working on large scale flood modelling, mapping and forecasting.

Ecosystem Health

Pressures on ecosystems are increasing due to population increase and economic growth. Interventions and human activities in water and soil systems put a strain on the ecological resilience of rivers, lakes, estuaries, coastal waters and groundwater. Fertilizers and substances alien to the environment such as herbicides and pesticides, medicine residues and (micro)plastics are an increasing threat to the quality of groundwater and surface water. As a result, the services that ecosystems provide to society are also under pressure. Human health is directly and indirectly dependent on the quality and functioning of ecosystems. Achieving healthier ecosystems for people and nature requires insight and information about the functioning and management of ecosystems. It also requires knowledge about sources, transport and the behaviour and impact of substances. The complex of stress factors requires integrated knowledge of the systems in relation to developments and human activities, in the chain of ecology, water quality, subsurface, hydrology, sediment, morphology and hydrodynamics. This knowledge is necessary for the design and validation of sustainable solutions for healthy ecosystems.

This programme is about developing and operationalising knowledge of the ecological and chemical functioning of water and soil systems to find answers to today's complex issues in the field of ecology, water quality, ecosystem health and human health. We use instruments, scenarios, design of solutions and design concepts. With this knowledge, perspectives for action and advice can be supplied to decision-makers.

In 2023 we focus on

- insight into the relationship between the functioning of ecosystems, biodiversity and their consequences on human health including developing an integrated suite of model instruments for exploring scenarios and identifying the impacts on nature and people.
- Anthropogenic substances, such as emerging substances and plastics: knowledge, tools and solutions to prioritize which substances to tackle where and how.
- Reducing greenhouse gas emissions and management of the carbon cycle through changes in water management and contributing to greenhouse gas sequestration and negative emissions from interventions in the water and soil system
- Reduction of Biodiversity loss. We work on concepts for ecological restoration (e.g., Marker Wadden) and assess results of Building with Nature projects with respect to biodiversity recovery. We participate in research on aquatic biodiversity and human health (with Radboud University) and through a number of EU projects.

Plastic waste and pollution

	Description
Line 1	**System knowledge:** Developing knowledge about water and soil processes with regard to water quality, ecology, subsurface and sediment, in relation to emissions, climate change, sustainable use of ecosystems and the impact on human and nature health. Particularly the role of biodiversity in ecosystem functioning and vice versa has priority.
Line 2	**Instruments and tools:** Developing a coherent set of instruments for diagnosing and simulating water processes and the impact on ecosystems and health. The set of instruments consists of simulation software, data science techniques and measurement and monitoring techniques. This line is in close cooperation with the Deltares Product Line Water quality and Ecology Software, and with the Experimental Facilities of Deltares.
Line 3	**Scenarios:** Analysing the impact of future scenarios (climate change, spatial developments) on ecosystem services, biodiversity and the health of people and nature. Exploring the influence of innovative solutions on the medium and long-term development of ecosystems.
Line 4	**Solutions Developing:** solutions for ecological and water quality issues. We focus on interactions between long term developments (such as climate change and social developments) and issues in ecology and water quality. This includes green remediation, nature-based solutions, methods for reduction of greenhouse gases and innovative design concepts.

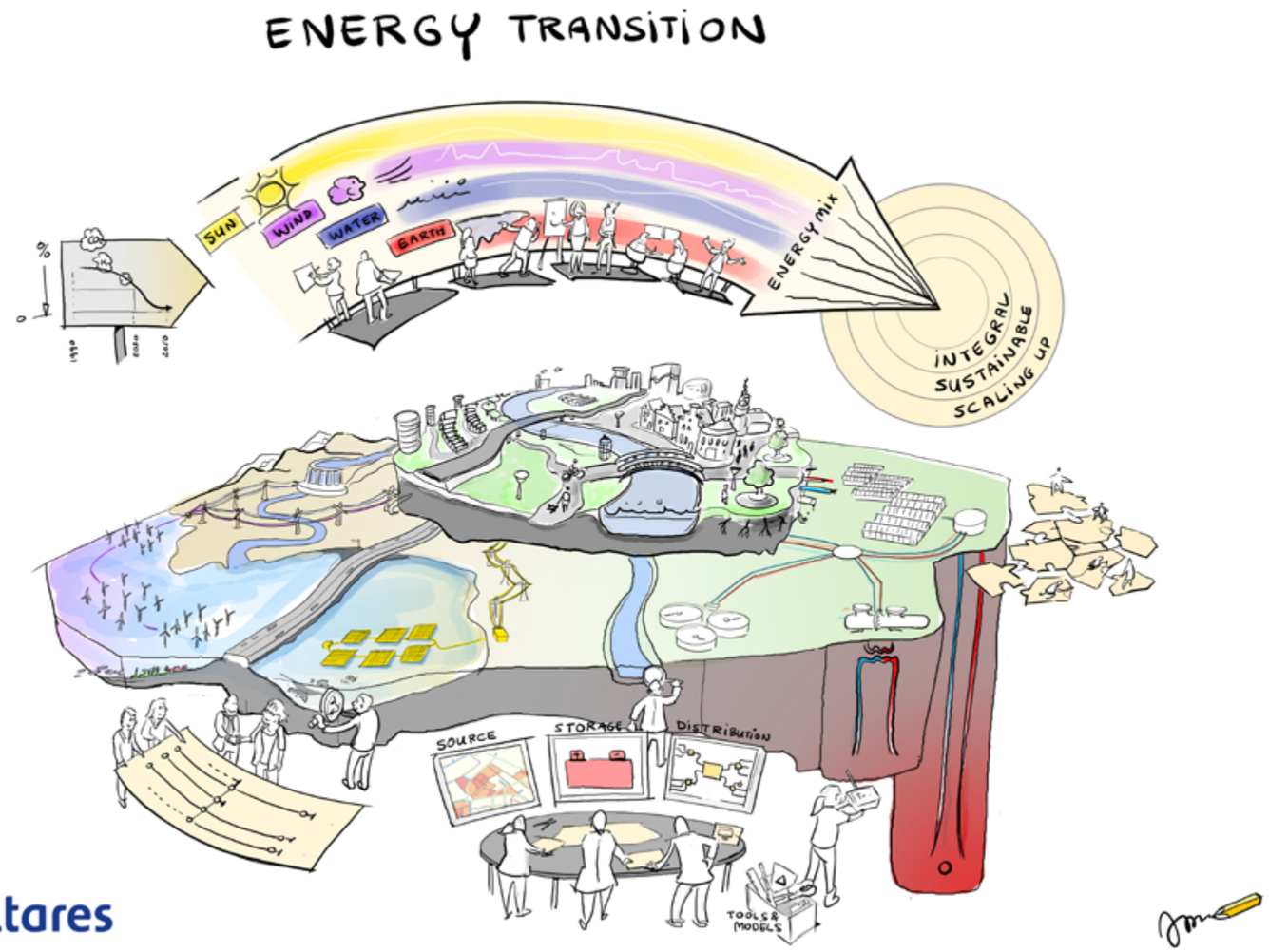
Partner type	Partner	Description of the cooperation
Dutch Government	IenW, RWS	Development of Delft3D FM model schematisations for water quality of large lakes and estuaries. Developing perspectives of action for the sustainable management of large waters, through KPP research contracts or in TKI, LWV and EU projects.
	LNV and EZK. STOWA, Waterboards, provinces and municipalities.	
Knowledge partners	WUR, WMR , NIOZ, NUS	Deltares contributes through its knowledge of the abiotic system and the lower trophic levels of primary and secondary production, and interacts with specialists of WUR, WMR , NIOO-KNAW of NIOZ on higher trophic levels (fish, birds, sea mammals). We operate as partners in research projects or as subcontractors in projects. A number of Deltarians have joint appointments at universities. National University of Singapore: 2 PhDs on plastic pollution. Cooperation with EU universities through H2020 en Green Deal UN World Water Quality Assessment.
Private sector	Consultants	Witteveen+Bos on water quality modelling. Bureau Waardenburg on ecological effects of infrastructure
Other (NGO, IFIs, citizens)		Natuurmonumenten (Dutch Nature Conservancy) World Wildlife Fund Netherlands (WNF). Stichting de Noordzee Programma De Rijke Noordzee

Sustainable Energy Transition

One of the largest global challenges is the sustainable energy transition. The Sustainable Energy Transition programme aims to facilitate and accelerate the sustainable energy transition with knowledge, system and process innovations. With our system knowledge of water and subsurface, infrastructure and technologies and socio-economic knowledge, we help to realize (inter)national and regional ambitions. The starting point here is affordable, reliable, practically feasible and socially acceptable solutions and technologies. The programme considers all parts of the knowledge and innovation process: system analysis, design aspects, measuring and monitoring, modelling, action perspectives, implementation and effects.

In the coming years, the programme is focusing on:

1. Sustainable energy services related to ‘heat’ from water and subsurface into collective district heating and cooling networks. These ‘heat’ energy services consist of the extraction, storage and transport of heat (and cold) integrated into collective heating and cooling networks to buildings. It includes the aquathermal and geothermal energy and thermal storage. The acceleration concerns the integration of all components of the heating and cooling systems: from multiple renewable heating sources and low- and high-thermal storage systems to the networks themselves. Smart control and cost-effectiveness of these heating (and cooling) systems are crucial.
2. Sustainable energy services related to ‘electricity’ from water and soil e.g., large-scale wind energy, and hydropower, solar energy and hydrogen. It concerns also the infrastructure for foundations, conversion, transport and storage. Our knowledge, tools, facilities, and models focus on cost-effectiveness, technical optimization, operational forecasting and risk reduction.



Outline of the main components of the Programmes Energy transition. Source: Deltares

Schematic of geothermal heating system. Source: Deltares

3. Spatial and ecological consequences and multifunctional use. Insights into the spatial and ecological consequences of large-scale application of energy services in water and subsurface systems (aquathermal, geothermal, solar and wind energy, hydropower, heat and cold storage, high-temperature storage), considerations for multifunctional use and strengthening biodiversity. Attention is also paid to the implementation of legislation and regulations.
4. System integration and supporting the scaling up. This concerns the development of integrated water and underground systems' models and the integration of heating and cooling and electricity systems to support the further scaling up of energy production and storage, as well as the development of transition paths and decision support instruments that contribute to responsible choices and considerations in energy policy.
5. Integration of energy transition with other societal transitions. Integration will take shape through the elaboration of area-oriented issues-driven working. In this way it will contribute to spatial and environmental policies and planning processes (in the Netherlands: in relation to the Omgevingswet).

	Description
Line 1	**Sustainable energy services in the form of heat** (and cold) from water and soil integrated into collective heat networks, with a focus on aquathermal energy and heat storage and to a lesser extent geothermal energy.
Line 2	**Sustainable energy services in the form of electricity** from water and soil: wind energy, solar on water, hydropower and transport & storage of green hydrogen.
Line 3	**Spatial and ecological consequences and shared use**. Insight into the consequences of large-scale application of energy services: aquathermal energy, geothermal energy, solar and wind energy, hydropower, heat cold storage, high-temperature storage.
Line 4	**System integration and support upscaling**. Integration of the energy transition with other challenges and transitions (this year a more concrete activity is the alignment between the climate change and the energy transition)

Partner type	Partner	Description of the cooperation
Dutch government	IenW, RWS	Contribute to the careful and sustainable use of water and soil in applications for energy transition and contribute to the missions. Collaboration mainly takes place in WarmingUP and the Aquathermie Network
	EZK, BZK, LNV, various provinces, municipalities, Waterboards, Union of Waterboards, RVO, PBL	Collaboration focuses on working on all programme lines
Knowledge partners	TNO, MARIN, KWR Water Research; EUR, Saxion University of Applied Sciences, UT, TUD, TU/e, UU, WUR	Cooperation on sustainable energy transition We work together with most knowledge partners in large consortia
International government and organizations	Europe and European Commission, UAE, Saudi Arabia, UK, Taiwan, Japan, Vietnam, USA, Bremen University, Sharjah University, University of Ghent, University of Hull	Collaboration focuses on working on programme lines 1 and 2. We work together with most knowledge partners on Cooperation on sustainable energy transition in large consortia
Private sector	offshore contractors energy utilities, engineering companies. network operators, insurers, hydropower-companies, heating companies, grid companies, parties in geothermal energy, installation companies	Together with companies, we work on innovations and knowledge development for the sustainable energy transition. Work mainly takes place in large consortia.
Other (NGO, IFIs, cooperation networks, citizens)	Network Aquathermie, Expertise Centre For Heat, Stichting Warmtenetwerk, Programme Aardgasvrij Wijken, RVO/UPTempo, STOWA, Geothermie Nederland, ICOLD, EWEA, Dutch Sustainable Energy, residents' collectives, living labs	Together we tackle knowledge sharing and make it available for application. Within WarmingUP and NWN! we work closely with knowledge dissemination partners. On a regular basis, consultations are held about the form in which products such as reports, guidelines, etc. are delivered.

Sustainability

The ‘Sustainability’ programme focuses on sustainable, socially inclusive and efficient management and use of water-related ecosystems and natural resources in deltas, developing sustainable, circular and nature-based solutions (including hybrid solutions) for societal challenges and providing a realistic narrative on how sustainable solutions contribute to sustainability ambitions in deltas.

Important points of attention for 2023 are:

- Connecting with our EU network and participation in European grant calls
- Inclusion of young professionals in the further development of specific topics
- Intensified dialogue with RWS and the Ministry of Infrastructure and Watermanagement (IenW) on Nature Based Solutions (NBS) in general and in more dedicated focus-topics to enhance cooperation and knowledge development

Clay ripening at the Eemsdollard

	Description
Line 1	**Quantifying the dynamics of NBS** NBS are inherently dynamic over time and in space. This poses challenges related to the prediction of their functioning over time and in space and on their long-term management in relation to the primary function they have to support. The large-scale implementation of NBS is hampered by the perceived uncertainty.
Line 2	**NBS inclusion and implementation** In this priority line we focus on designing processes and instruments that enable successful implementation of nature-based solutions. Specific topics are: NBS implementation, inclusive approaches and economics and finance.
Line 3	**Urban NBS** are located in urban areas, addressing challenges that are characteristic of those contexts. Separate methods and knowledge development on the topic are needed to provide cities worldwide with more knowledge and capacity to evaluate and implement NBS where feasible.
Line 4	**Beneficial re-use** focuses on the optimum beneficial and circular sediment use, by utilizing locally available sediment in various applications. On maximum leverage of natural processes (i.e. Building with Nature). And on technology development. This line is linked to dynamics of NbS in space and time and to socio-economic consideration to assure upscaling and mainstreaming.
Line 5	**NBS for extreme events drought** is a yet underdeveloped set of sustainable measures world wide (only 4% of reported NbS-projects deal with drought related topics). Yet the potential is there to include assessment of their possibilities in many IWRM studies. Natural Water Retention Measures are being focused on. Additional coupling with other IWRM measures, taking an Ecosystem-based Adapation (EbA) approach is key.
Line 6	**Carbon cycling** Nature based solutions impact on carbon cycling, as both carbon sequestration and emission of methane and CO2 may take place. The analysis of emission and uptake of carbon is not as straight-forward as fossil-fuel based carbon emissions. Deltares facilitates this line with an experimental facility for carbon cycling experiments, both in the field and the laboratory .

Partner type	Partner	Description of the cooperation
Dutch Government	HWBP, RWS, WVL, IenW	• HWBP WDOD Dijken en Natuur (Dike and Nature) • Definition of guidelines design subsurface landscapes • Flood plain vegetation and bank erosion • Water as Leverage cooperation IenW. ISBAM development with RWS. Preparing for Mainstreaming NBS coastal project with RWS (Interreg MANABAS)
	RVO waterboards Province Groningen/ Delfzijl Municipality	• Cooperation with RVO on social inclusivity • Waterboard “Aa en Maas” – risk-based vegetation management • Ecoshape-projects such as clay ripening.
Knowledge partners	IMARES, WUR, TUD, UU, UT, NIOZ National University Singapore	Many projects, including projects with Ecoshape, NWO, TKI etc.
International government and organizations	IUCN, Worldbank WWF/TNC/Wetlands International, ADB/ WB/IADB, USACE, USACE, KICT, IAHR/CEDA/PIANC	• Global Standard on NbS including implementation • Dealing with uncertainties in NbS • Cooperation EU/international projects • NbS networks
Private sector	Ecoshape	
Other (NGO, IFIs, citizens)	WWF, Wetlands International	RVO CoP Nature-based solutions

Realtime Information

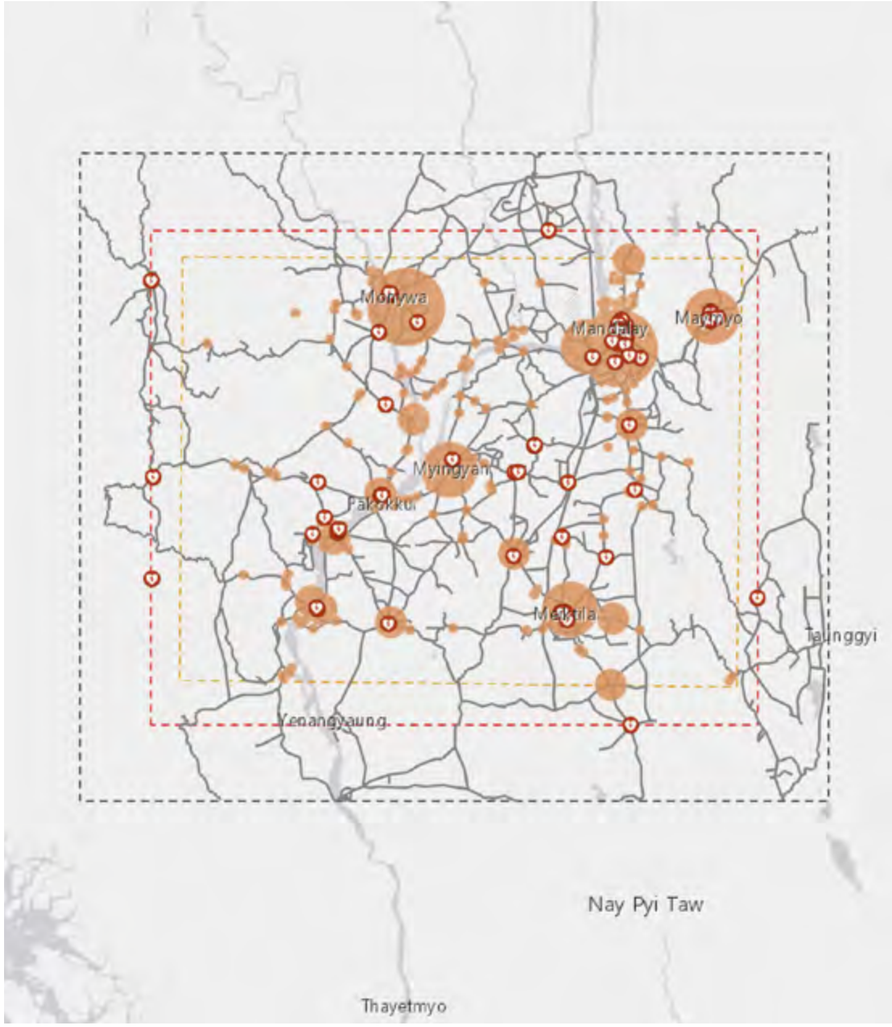
Realtime is about water and subsurface related operational information to support decision making in the context of crisis management and daily operations. It contributes to Moonshots 2 and 3.

The main challenge in this field is to optimally combine the two sources of operational information: real-time data and model outputs. In addition, to achieve added value information should be tailored to the needs of the user. The programme distinguishes between three types of application areas:

1. Reducing the effects of rain-induced, riverine and coastal flooding, and environmental incidents. The timescales for these applications are relatively short: hours to days. This means that rapid availability of accurate forecasts is important for crisis management, so that timely warnings can be issued, and appropriate measures can be taken. After the occurrence of an event information is needed to effectively combat (the consequences of) the event and to speed up recovery.
2. Reducing the effects of drought and salinization. The timescales for these applications are relatively long: weeks to months. In this case, anticipatory measures are based on probabilistic forecasts, accounting for exposure and vulnerability to drought or salinization. During and after the event, actionable information is needed to effectively manage the adverse effects and speed up recovery.
3. Optimizing the day-to-day management under normal circumstances. The challenge here is to make quantifiable trade-offs between conflicting interests, for example those in the fields of energy supply, agriculture, nature, water quality and shipping.

The ambition of the programme is to strengthen and expand Deltares' position in the domain of real-time information, forecasting and early warning. Concretely, in 2023 we will

- Further develop the global forecasting systems for storm surge, flooding, and drought, with special focus on integration of these systems to be able to address compound events.
- Develop state-of-the-art seasonal forecasts of the Rhine and Meuse catchment implemented in the innovative forecasting platform.
- Develop state-of-the-art operational system for conjunctive management of groundwater and surface water.
- disseminate results from these systems through services, such as the Deltares Next Generation Drought Index (google earth engine application).
- Develop the downstream applications aimed at producing locally relevant information, such as automatically generated local flood forecasts, and drought indices.
- Explore potential of global forecasting and real-time information systems related to groundwater, water quality, health, and fires.



Impact of floods on the community in the Mandalay region, by assessing road infrastructure criticality and connectivity between population centres and hospitals.

	Description
Line 1	**Global to local multi-hazard forecasts** Early warnings can significantly reduce the impact of extreme events, such as floods and droughts. Forecasting systems with global coverage can contribute to the Sendai Framework goals of making early warning available to all. This motivates Deltares to further develop globally applicable, locally relevant forecasting systems, including GLOSSIS and GLOFFIS.
Line 2	**Operational drought management in the Netherlands** In recent years Europe has been struck be prolonged periods of drought. In order to reduce the vulnerability of society to drought, the sharing of data and the availability of real-time information and drought hazard and risk forecasts are recognized as key factors that contribute to balanced decision making. Deltares aims to take the lead in bringing together the available expertise and tools.
Line 3	**Urban and flash flood forecasting** Generating useful flood warnings for urban and flash flood prone area's poses requirements on the forecasting process that clearly differ from those in the large-scale, global approach. We therefore put our focus on techniques such as radar nowcasting, rapid, high-resolution inundation models and the incorporation of local information for hazard assessment and mitigation is essential.
Line 4	**Decision making under uncertainty lab** aims to launch a Decision Making in Uncertainty Lab. This is envisaged to be a facility by Deltares and partners from which knowledge is gained on dealing with uncertainties, forecast-informed decision making and the role of nudging and the influence of the human forecaster on the quality of forecasts.

Partner type	Partner	Description of the cooperation
Dutch Government	RWS	The work for RWS is prominent: there are many links between research topics in the programme and developments at RWS.
	Waterboards, Provinces and Municipalities	Mostly market projects in which Deltares solutions are implemented. Our ambition is to strengthen our cooperation on topics related to drought, and ground water.
Knowledge partners	TUD, WUR	The chairs at TU Delft and Wageningen University provide the connection between the programme and national knowledge partners. Joint efforts are employed in the fields of data assimilation and hydrological forecasting, through NWO and STW projects, with PhD and MSc students involved.
International government and organizations	Red Cross Climate Center, ECMWF, JRC	Collaboration with parties such as the Red Cross Climate Centre (NGO) and ECMWF (meteorological service). This includes communities such as the Global Flood Partnership and HEPEX, and initiatives such as the "Anticipation Hub". H2020 projects and projects for Copernicus are carried out that are related to and co-financed by the programme.
Private sector	Consultants	This varies from hydropower agencies to engineering consultants.
Other (NGO, IFIs, citizens)		Collaboration with parties such as the Red Cross Climate Centre (NGO) and World Bank in projects.

Risk Analysis and Management

This methodological research programme covers the fundamental and quantitative analysis of risk and the development of (probabilistic) techniques that can be applied in projects concerning risk and reliability, for instance in the fields of natural disasters and infrastructural assets. Additionally, within the programme frameworks are developed for risk-based decision-making concerning climate adaptation problems and the use of data science techniques within quantitative risk analysis is explored. In this way, the programme delivers an important contribution to the Deltares Moonshots 1, 2 and 5.

Risk management plays a crucial part in safe and sustainable spatial planning of deltas which makes it relevant for many Deltares projects. Both the probability and the consequences of undesirable disruptive events (such as flooding, other climatic events or unavailability of critical infrastructure) need to be reduced. At the same time, however, the measures taken to that end need to fall within the boundaries of acceptable societal costs and limited space. Hence, the knowledge on existing risks and available mitigating measures is of utmost importance.

A variety of (probabilistic) tools is used for the quantification of risks. These tools present ways of determining both the risks and the effects of mitigating measures. Probability of occurrence of events (risk analysis) and their consequences in terms of casualties, economic damage, availability of (critical) infrastructure, indirect damage, societal disruption and the lack of basic needs. The combination of probabilities and consequences result in relevant risk indicators.

Risk analysis offers important advantages in the assessment of existing and the design of new infrastructure. The probabilities of both failure and unavailability can be determined more accurately, which allows the responsible increase of the structure life span and decrease of costs. Risk analysis and management can lead to safer and more cost-effective solutions in the design and construction of new infrastructure. In this, the use of data science techniques offers new possibilities by enabling access to big data.

The uncertainty associated with the magnitude of the effects of climate change and the associated consequences demands a risk-based approach. To facilitate that, risk-based frameworks are being developed in this research programme to support both decision and policy making concerning climate adaptation questions.

This programme provides essential building blocks for other research programmes such as Flood Defences, Natural Hazards, Infrastructure Networks, and Renewal and Renovation.

	Description
Line 1	**Natural disasters:** Quantification of consequences and risks of natural disasters such as floods, storms, droughts or landslides.
Line 2	**Infrastructure:** Reliability analysis of critical infrastructure for risk-informed adaptation, replacement and reinforcement measures.
Line 3	**Risk-informed climate adaptation:** Assessment of changes in climate-related risks for various climate scenarios for supporting decision-making in climate adaptation.
Line 4	**Data science for Quantitative Risk Analysis:** Quantitative risk analysis using advanced data science techniques such as artificial intelligence (AI), data fusion or Machine Learning (ML).

Partner type	Partner	Description of the cooperation
Dutch Government	IenW RWS	Further development of methods and tools for quantifying flood risk, reliability of flood defences and for optimizing reinforcement designs in the BOI and HWBP programmes.
	City of Amsterdam	Development of probabilistic assessment tools for quay walls and bridges with focus on foundations (wooden piles).
Knowledge partners	TNO TUD	The cooperation with TNO focusses on development of methods and guidelines for design and assessment of infrastructure. Additionally, together with TNO and TU Delft, Deltares has initiated a Community of Practice around risk and reliability called the “Delft Reliability Exchange”. In this CoP, methods and practical examples are presented and discussed in regular lunch lectures and events.
International government and organizations	DHS, FEMA, CEN & ISSMGE	Deltares develops the “Community Flood Resilience Support System (CFRSS)” in cooperation with the DHS (FEMA) to help communities understand, assess and improve the potential consequences of flooding and their own resilience. Collaboration with CEN and ISSMGE (International Society of Soil Mechanics and Geotechnical Engineering) on modernizing standards
Private sector	ProRail	Establishing reliability frameworks and reliability-based assessments of railway track safety (embankments).
Other (NGO, IFIs, citizens)	UNESCO	We partner with UNESCO to carry out flood risk analyses in south-east Africa (Zimbabwe, Mozambique).

Adaptation and Implementation

Adaptation and implementation are complex and require continuous reflection and innovation. This is certainly the case when climate adaptation is affected by other challenges facing society such as the energy transition, housing construction and biodiversity loss. The question is: how can we improve the options and their implementation and make them more effective? Not just in theory but also in practice. This methodological programme adopts the technical solutions/knowledge as a basis. It focuses on innovative, adaptive and inclusive measures and planning processes - and on the monitoring of progress before, during and after change - in order to learn together and make adjustments in good time so that we, as Deltares, can enhance the impact on society of applied research in the area of water and the subsurface. With the activities of the Adaptation and Implementation programme, we hope to help our partners and clients to improve their understanding of possible solutions for adaptation, taking into account other transitions and developments facing them (such as urban development, the energy transition and increasing inequality). We want to help them improve implementation and adaptation processes with practically applicable methods and tools.

Saint Louis, Senegal

	Description
Line 1	**Solution space** develops a method for the better determination of the solution space in order to adapt the water system to climate change and other changes in society. We analyse technical solutions, public acceptability, the time and resources required for implementation and institutional factors that may hinder or further solutions.
Line 2	**Implementation gap** explores which factors can hinder or enable the implementation of policies, programmes, plans and projects and develop methods to further implementation. We look at key elements such as legal and institutional frameworks, inter-agency collaboration and whole of society approaches, social inclusion and sustainable financing.
Line 3	**Monitoring & Evaluation p**rovides a range of parties with tools and methodologies for measuring and monitoring the effectiveness of climate adaptation. The development and application of these tools support the estimation of the societal and economic effects of innovative strategies and solutions at the national and regional scales.

Partner type	Partner
Dutch Government	Ministry of Infrastructure and Water Management, RWS, Delta Commissioner
Dutch government	Municipality of Gouda, Province of Friesland
Knowledge partners	Radboud University; TUD
International government and organizations	World Bank, WMO, IDMP, APFM, OECD
Private sector	Alliance for Global Water Adaptation

Knowledge facilities

Deltares has a number of unique knowledge facilities at its disposal. They include software, data and experimental facilities and key enabling technologies. The Networks and University Positions Knowledge Facilities support Deltares input for national and international knowledge and policy bodies such as the IPCC and ENW, and fund appointments of professors and senior lecturers at a range of Dutch and foreign (applied) universities. The knowledge facilities support and inspire the mission-driven programmes. Requirements of the mission-driven programmes are supported by the knowledge facilities on the short term. On the other hand, strategic research based on the knowledge facilities aims to inspire the mission-driven programmes by providing new opportunities to generate impact on the longer term. In 2023, we intend to further boost the effective coordination of the various knowledge facilities, coordination with the mission-driven programmes and the application of enabling technologies. We will continue our efforts to accelerate our digital ambitions (Deltares strategic agenda 2021-2025). Additional attention is required for key scientific positions at (applied) universities as well as the scientific impact of our experimental facilities.

Enabling Technologies

The objective of Enabling Technologies is to support our mission enabling delta life by testing key technologies in data science, modelling and (remote) sensing and proto-typing solutions and products which make use of these technologies. Technological innovations in these fields can increase the impact of solutions Deltares is working on. For example, the speed at which data currently becomes available in increasingly higher spatial and temporal resolution offers huge opportunities to increase the value and scale of solutions in the realm of ‘Enabling Delta Life’.

The Program Enabling technologies therefore contributes to all the moonshot objectives. It creates opportunities to increase the impact either by offering new concepts which can be used to scale-up or opportunities to increase reliability and trustworthiness of the solutions. The Program’s way of working is by facilitating and inspiring Deltares’ Moonshots and research programmes. Facilitation will take place through co-opted projects. Inspiration is generated through educational and networking activities. Since the programme focusses on cutting edge technologies, it pays attention to additional aspects of innovation relevant for Deltares’ mission areas. Testing of new innovations and technologies is done in projects built around short innovation cycles with room for failure or unexpected results.

Testing of a fiber optic sensing pole as an innovative solution to monitor the dynamics of harbour sludge

The following activities are foreseen in 2023:

- Continuation of the Hybrid Modelling Initiative focused on physics-based AI and numerical modelling: tech-scans and experiments.
- Exploration of xPU's
- Cloud computing: beyond horizontal and vertical scaling?
- Continuation of the EO2model initiative focused on automation
- Hybrid Modelling, the combination of data, numerical modelling and other analytical techniques to optimize stakeholder workflows.
- Physics Informed Machine Learning. Emerging techniques in this field have the potential to disrupt our current practices.
- New Sensors will be explored on the basis of the launch of new satellite missions e.g., SWOT (Altimetry/Coastal and Inland water level), NISAR (L-band SAR/Ground Motion), FLEX (Fluorescence/Vegetation)
- Enhancing our experimental research infrastructure and monitoring techniques for subsidence, subsurface characterization, infrastructural objects, for the composition of groundwater, flow and wave measurements, for ecosystem health and water quality

ET will contribute to all five moonshots.

Enabling Technology Data Science Community Meeting

	Description
Line 1	**Future Modelling** explores technologies for modelling physical processes which will be state-of-the-art in 5 to 10 years' time. The possibilities to model physical processes change under the influence of developments in data science, cloud services, visualization, high performance computing. We explore the possibilities and consequences by executing scans and pilots.
Line 2	**Future Sensing:** Measurement and monitoring technology help to understand physical systems and in validating and improving (data-) models, through model calibration, monitoring long term trends and making data sources available. This programme line scans and validates new developments in the field of monitoring and monitoring platforms and in the field of processing of data for modelling.
Line 3	**Data Science** continuously scans, makes use of hackathons and pilots, and developments in data science which have the potential to increase our impact in the mission areas. Its goal for Deltares is to support the work done in the mission areas with knowledge and tools, with a focus in the fields of AI and machine learning. This is a programme line for the foreseeable future, until innovations within this area are sufficiently handled by the wider organization, without the need for stimulus from the programme.
Line 4	**Earth Observation** Remote sensing has a special role within the focus area of the first three programme lines and within their respective connection. We will further strengthen the knowledge and the portfolio which Deltares already has in impactful applications of this technology in the mission areas. Important motives are the need of consistent and frequent data for monitoring and rapid response, fast developments in availability of earth observation data and global coverage of these data.

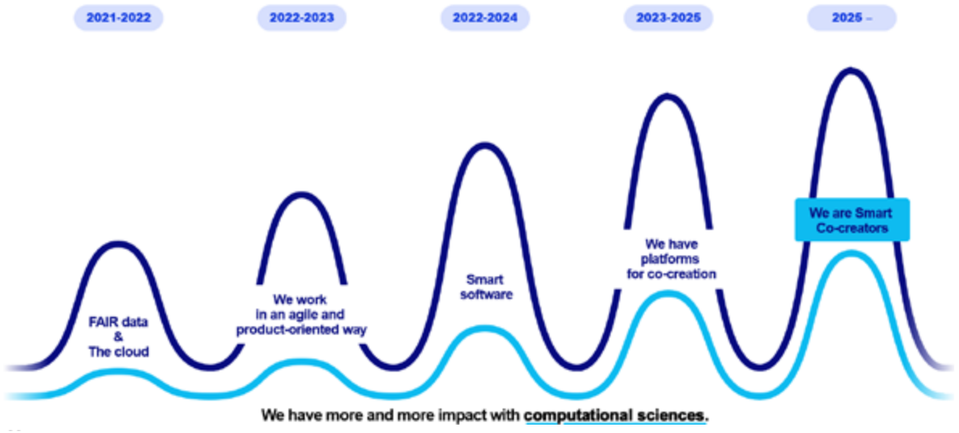
Type partner (national and international)	Partner	Description of the cooperation
National	Digishape, NL AI Coalition	Triple-Helix cooperation on data science en AI
	Marin, NLR, TNO	TO2-institutes
	TUD, TU/e, UU	University research on computational technology, AI, (remote) sensing
	Consultancies, contractors, SMEs	Cooperation in the Digishape programme
	RWS, Waterboards, ProRail	Applied research on water management and large infrastructures.
International	Leeds University (UK), University of Naval (Canada)	University research on computational technology, AI, (remote) sensing
	Imec, ESA	Research on remote sensing en earth observation
	Microsoft, Google, Amazon	Tech-partners on cloud computing and platform technology

Digital Transformation in Software and Data

In order to create impact on the complex societal issues with our domain knowledge, we need the smartest people, all relevant technologies and co-creation with national and international stakeholders and partners. As stated in the Deltares Strategic Agenda 2021-2024, this requires an acceleration in updating our main software products, in strengthening our capacity in data driven technologies and in our data management and cloud infrastructure. And in addition, this requires a newly designed way of co-creation between Deltares and other knowledge institutes, private parties in the water and subsurface sector and governmental stakeholders.

The implementation of our digital transformation roadmap started in 2022 with the first priority to improve of our data management following the FAIR principles, and the extension of our cloud infrastructure. Moreover, we introduced a more agile way of organizing the maintenance, development and renewal of our software products. We created 5 Product Management Teams which coordinate the development of our core software products: Hydrodynamics & Morphology, Catchment Hydrology, including groundwater, Geotechnics and Flood defences, Water Quality & Ecology and Operational and Planning Systems.

These changes, that will find their stabilized implementation in the coming year or years, are necessary to enable the co-creation on data and software with other parties.



Software

Deltares' software – most of which is free-ware and/or open-source has been world-leading in several application areas for decades. In order to maintain this position our software products need to be upgraded and renewed in order to incorporate newer developments like Machine Learning approaches, Earth observational techniques (spaceborne, airborne, terrestrial), faster computational algorithms and meta models, Cloud Computing, high performance computing, web services, data driven modelling and experiments with new, modular architectures.

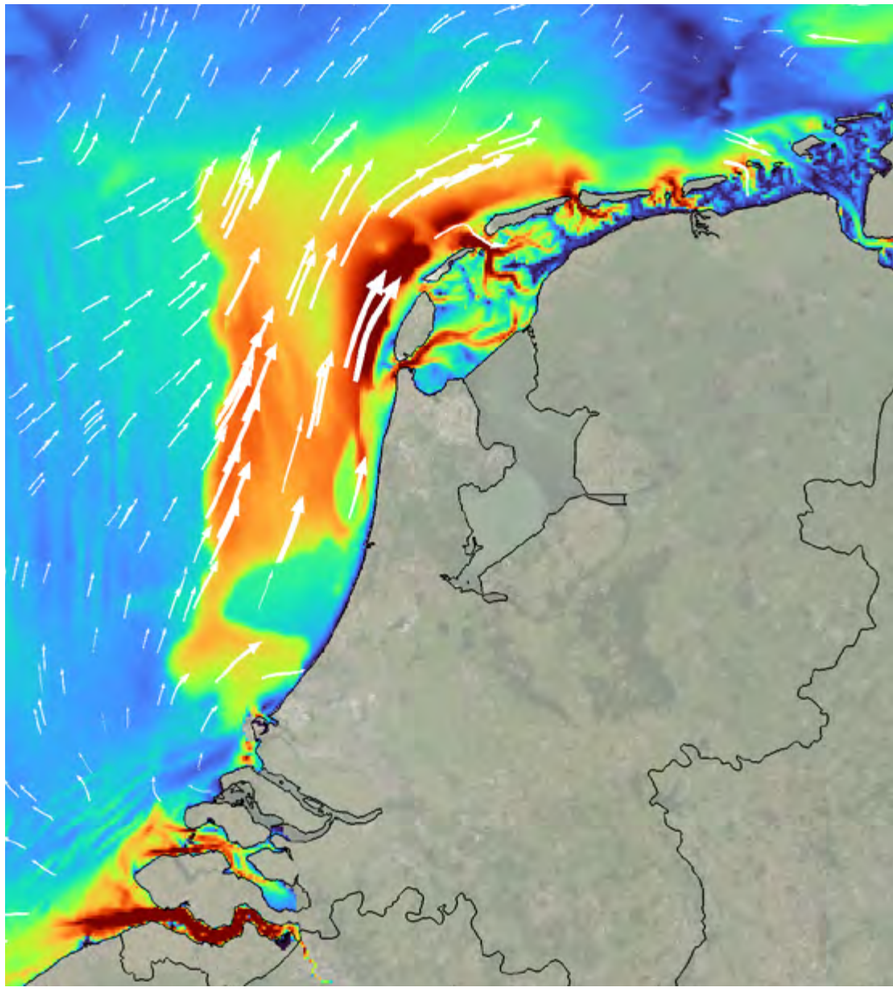
For some products this implies major changes or even renewal of large parts of the software code. A challenge Deltares is facing here, is that the current products have to be maintained while the new versions are being built. This requires extra capacity of specialists and financial sources. To face this challenge, we need to co-operate with other parties, and find multiple financial sources. On both of these topics we are having dialogues with our stakeholders.

Developments on machine learning/artificial intelligence are for example a data-model integration tool to predict shoreline change globally, the AI-driven PROTIST algae modules that will be integrated in our water quality software, the HIPPO Lab for decision support on climate change mitigation and adaptation, analysis software of observed water motions in our experimental facilities using video, a method for leakage detection in pipelines, and quantitative risk analyses of flood risk and constructions, among many other examples.

On Earth observation, in the "EO2Model" project we investigate automating the pipeline of Earth Observation-products towards model input and model state updates, and we are integrating satellite information in our flood mapping. We use satellite data to obtain large-scale data on dike and infrastructure deformation.

Examples of projects on Digital Twins are the Digital Twins of the ocean and the subsurface, infrastructure networks and transport (FAIRWAYS), of the Rhine-Meuse Delta (SALTI solutions), natural hazards (interTWIN).

To further accelerate this process of enhancing our digital capacity, we use our moonshots to inspire challenges that ask for applying new digital techniques. In order to use a wide range of expertise and experience, we will build teams to work on these challenges that consist of specialists from Deltares and from other parties. A dialogue on how to shape co-creation with private parties and governmental stakeholders has started in 2022 and will be continued in 2023. In order to finance these activities, we plan to combine different sources of funding.



Flow patterns in the North and Wadden Sea computed by Delft3D-Flexible Mesh

Data

As the amount and diversity of data is growing, and the techniques for analysing data develop rapidly, the FAIR management of data facilities plays an important role in the digital transformation. In this way we can meet the growing demand for (global) data: on the one hand by providing high quality data and information, as well as information developed using data engineering and data science, and on the other by developing data-driven methods and software. The main activities in 2023 include:

The Blue Earth Initiative is to enable well-informed and interactive decision-making in the field of integrated water management and integrated coastal zone management. Our ambition is that clients and partners are served faster and better with the right solutions for their water management and planning challenges. The Blue Earth Platform consists of state-of-the-art data, models and dashboards that are interconnected in the Deltares back office. The Blue Earth Platform makes global datasets freely available (Blue Earth Data). The Blue Earth Platform also includes the option for modellers and policymakers to combine datasets and tools and, in that way, to support planning and design processes through an integrated approach. The 2023 activities will focus on:

- Making new global datasets available inside and outside the organisation (Blue Earth Data)
- Further development of tools for connecting data and models for efficient modelling and data collection
- Piloting the application of the Blue Earth Platform as an integrated approach in designing water resources strategies in two case studies: the EU STARS4Water project (water resources availability in the Rhine catchment) and the Joint Cooperation Programme for water security in Egypt.

European Data Infrastructure: through the European research project C-Scale, Deltares is contributing to the development of a European infrastructure for storing Copernicus datasets and making them available to science. This project will support the data facility programme and contribute to the digital transition. C-SCALE solutions can be seamlessly integrated in the European Open Science Cloud supported research and innovation processes and practices.

Data services include high-quality digital terrain models (DTM/DEM) with high spatial and temporal resolution, climate services for supporting (a) the implementation of adaption measures (through the EU project CLIMATEUROPE2) and (b) climate action from local to global (Water and Climate Coalition initiative), and data on groundwater salinity based on FRESHEM earth observation technology.

Access to data from experimental facilities. The availability of validated data and information based on measurement data is essential for knowledge development. To this end, we develop methodologies that are geared towards improving access to data from our experimental facilities for the purposes of further data analysis and/or model improvements.

Experimental Facilities

Facilitating and inspiring moonshots
Deltares uses experiments to gain new insights and to validate and implement these insights, for example in prediction models. In addition, monitoring is used to identify long-term trends and to perceive insight into behaviour and condition. Moreover, technological developments and digitization offer opportunities to achieve greater impact.

Deltares carries out high-end experiments in state-of-the-art research infrastructure (in the lab, experiment hall and field), with reliable and verifiable measuring techniques. We achieve this by deploying a wide range of research infrastructure and by accelerating and strengthening these in partnerships and networks. Our ambition is to study phenomena, validate methods and come to verifiable experimental datasets. We want to increase and broaden the added value of the experimental facilities in our research. We do this by giving incentives to the realization and application of new facilities, applying the facilities to new fields of knowledge and implementing new or improved measurement techniques in experiments. In doing so, we consider the challenges in our research programmes and moonshots. The Program's way of working is by facilitating and inspiring Deltares' Moonshots and research programmes. Facilitation will take place through co-opted projects. Inspiration is generated through educational and networking activities.

Focal points in 2023
In 2023 experimental developments will be supported in model, lab and field related to the interpretation of the effects of climate change, the influence on our eco-system and our living environment and the effects of this on the infrastructure including the energy transition. We will be making data sets available and linking experiments to the

Investigating the wave impact reduction of willow trees in the Delta Flume

digital transformation. Furthermore we choose to focus on upcoming external trends to give an impulse for further enhancement of new research infrastructure. In 2023 this will be on the biochemical research infrastructure. In these facilities research is taking place into plastics in water and underground (Maelstroom project), the use of RNA DNA techniques for tracing purposes and the emission of greenhouse gases from water and soil (DuNag project).

In 2023 we will continue to bring together the expertise in terms of discipline and technicians, in order to optimize the use of the facilities. We have the ambition to work together with other partners and stakeholders, amongst others within the European Union framework programme (GeoLab). For selected topics we want to stimulate the use of Deltares' experimental facilities by our researchers to increase our scientific credibility and visibility. This is to create opportunities to broaden the knowledge base of our experts in physical modelling and to enable our experts to make use of the scientific opportunities that our facilities provide. These efforts should result in increased scientific impact.

Examples that underpin the value of our facilities are the tests that are carried out in the water soil flume for the TKI PRISMA project on alternative dredging methods. In 2023 geo centrifuge tests are being performed as part of the InPad project for of pile foundations and as part of the TISCA project for sewer systems. Innovative silent installation methods for offshore wind foundations are tested in the SIMOX research programme. At last, the Woods versus Waves programme, is preparing for a follow-up of the Deltaflume experiments on the attenuation of waves by woody vegetation.

Networks and University Positions

Alliances with universities
To achieve the goals and ambitions of Deltares in the area of mission-driven research and the moonshots, active alliances with universities and institutes of higher education are essential. These close relationships are seen, on the one hand, in shared chairs, associate professorships, lecturers, PhD students and postdoctoral appointments and, on the other, in the joint development of projects and research in NWO/TTW programmes, NWA and European research programmes. We will intensify and expand these relations by facilitating new chairs and appointments, e.g., in the fields of geotechnics, water quality, data science, water resource management, and land and water management in the context of carbon cycling.

In 2023, Deltares will facilitate the appointment of more than 20 professors (full-time or part-time), 30 university and college lecturers and 80 doctorate students. The financing/co-financing and substantive supervision of the PhD students is organised through the research projects in the programmes. The guiding principle remains that Deltares participates only in projects that match the objectives of its own research programmes and the knowledge questions related to the Deltares moonshots. Through this programme, we facilitate long-term collaboration with universities and universities of applied sciences (HBOs) through the exchange of staff targeting the development of the core disciplines through joint scientific research for the purpose of developing and maintaining the knowledge base of the mission-driven programmes. The positions are at a range of Dutch universities (Delft University of Technology, Utrecht University, Radboud University, the University of Amsterdam, VU Amsterdam, University of Twente, Wageningen University and Research Centre), Dutch Universities of Applied Sciences (HBOs) of Saxion, Hogeschool Zeeland and Hanze Hogeschool, and at international institutions (National University of Singapore, University of Illinois). The alliances focus on the disciplines of hydraulic engineering, geo-engineering, hydrodynamics, hydrology, morphology, ecology, water quality and health, hydro-informatics, informatics data science, climatology and climate adaptation.

Networks
To maintain the knowledge base, and for the exchange of knowledge and the establishment and maintenance of alliances in research and innovation, the Deltares knowledge facilities finance broad-based networks with research institutes and the private sector. These networks have a cross-programme coverage and are of strategic importance in facilitating the development of mission-driven research. The networks operate on a national, European or global scale. The projects arising from the network activities are financed by one of the 15 research programmes.

At the national level, these are networks in areas such as river research (NCR), coastal research (NCK), flood risk management (ENW), underground construction (COB) and digital innovation in the water sector (Digishape).

At the European level, they are mainly networks that target collaboration in research and the definition of the knowledge agenda for policy-making and support in the field of water, climate services, environment and geo-engineering such as Water Europe, Euraqua, Sednet, ELGIP, NICOLE and NORMAN. The European network activities focusing on strengthening the position of Deltares in the Horizon Europe research programmes. In 2022, this resulted in a large number of new EU projects, e.g.: ClimatEurope2 (climate services), BlueAdapt (health risks in blue environment), STARS4Water (future water resources availability), NAPSEA (nutrient reductions); PREPSOIL (EU soil mission), MIRICA (multi-hazards), Danube4all (river restoration), CLIMAAX (climate risks), PEERS (adaptation pathways) UP2030 (urban planning), ULTFARMS (aquaculture), TRIDENT (deep sea mining), OBAMA-NEXT (new observations services marine environment), NINFA (groundwater quality), SEDIMARE (sediment transport) and more.

At the global level, network activities are supported in the field of climate (IPCC), hydraulic engineering (PIANC), nature-based solutions in water management (Ecohydraulics) and the Collaborative Modelling community of practice. A new network initiative is the International Panel for Deltas and Coasts (IPDC) that will be launched during the UN-Water 2023. Main objective of the IPDC is supporting the implementation of tailormade climate adaptation actions in deltas and coastal zones by developing knowledge and tools and capacity building activities.

4 Financial framework

This 2023 Activity Plan was drawn up to apply for the SITO institute subsidy in the context of the subsidy scheme for institutes for applied research of the Ministry of Economic Affairs and Climate (dated 1 February 2018, no. WJZ/17203973). The institute subsidy for the implementation of Strategic Research by Deltares has been set with a ceiling of €20,937,000 for the 2023 financial year.

The 2023 Activity Plan is in line with the knowledge and innovation agendas of the relevant ministerial departments and Top Sectors. The contribution to societal themes - as set out in national and international agendas - has been elaborated and explained in the previous chapters. This chapter provides an indication of how the subsidy contributes to the Mission-Driven Top Sectors and Innovation Policy (MTIB).

Our estimate is that Deltares' turnover will consist of at least 60% of non-economic activities. The institute subsidy will not be used for economic activities. As in previous years, the rates for activities covered by the 'institute subsidy' and as described in the 2023 Activity Plan will be submitted to the Ministry of Economic Affairs and Climate (EZK) in December 2022 together with an auditor's report.

Commitment to mission-driven working

In 2023, approximately two-thirds of the institute subsidy (approx. 12,5 million euros) will be used directly for activities that contribute to the national missions and international agendas as described in the KIAs. Approximately €8 million of the total institute subsidy will be used for activities relating to the knowledge facilities.

The first table shows the indicative budget allocation for the mission-driven programmes. The second table shows the indicative budget allocation per moonshot, for the Knowledge Facilities and for the Programme Management.

The final table shows how the budget is allocated at the level of the KIAs. The largest share goes to the Agriculture, Water and Food KIA (AWF KIA).

Commitment to collaboration with the private sector

One of the tasks of Deltares is to strengthen the innovative capacity of Dutch business. Private partners therefore play an important role in articulating needs and questions, and in the application of knowledge, both as financiers and co-creators. The most important private sectors work in construction or hydraulic engineering, or they are consultancy and engineering firms from both the Netherlands and other countries.

Nevertheless, the government remains the largest purchaser and user of the knowledge and innovations in the field of delta technology. The private sector is expected to contribute approximately €10 million annually to the applied research conducted by Deltares. This contribution is made to JIPs (joint industry projects), PPPs (with and without TKI subsidy) and Horizon Europe projects. Deltares is also making its own contribution to European research projects amounting to approximately €2 million of the institute subsidy. Deltares is committed to multiple types of alliance – such as those mentioned above, but also new activities - that specifically target SMEs and start-ups. Deltares interacts with many Dutch SMEs. Those contacts involve transferring knowledge to SMEs, acquiring knowledge from SMEs or working together on applied knowledge development. Over 200 SMEs call annually on Deltares (and vice-versa) for their projects. In addition to this project-related

Indication of program budgets for SITO institutional subsidy 2023	**Indicative budget** Euros x 1,000
Mission-driven programmes	
Long-term delta developments	825
Seas and coastal areas	725
Rivers basins and Estuaries	1,100
Resilient cities	825
Infrastructure systems	950
Infrastructural Renewal and Renovation	725
Flood Defences	725
Water Resources	825
Natural Hazards	725
Ecosystems Health	1,050
Energy transition	1,050
Sustainability	725
Risk analysis and Management	725
Real-time information	725
Adaptation and implementation	725
Sub-total	12,425
Knowledge facilities	
Digital transformation: software and data	2,750
Experimental Facilities	950
Enabling Technologies	1,050
Knowledge Networks	350
University Positions	1,050
Emerging topics	1,675
Sub-total	7,850
Subtotals	
Total Mission-driven programmes	12,425
Total Knowledge Facilities	7,850
Programme Management	662
Total	**20,937**

Indication of programme budgets for SITO institutional subsidy 2023

collaboration, there are also innovation projects that are executed without invoicing or by using external funding. Since 2019, we have a service desk for SMEs and start-ups. SMEs and start-ups can also make use of the 'Technology Consult' (a one-day consultation) free of charge and Deltares is providing increased access to the experimental research facilities (using quarterly SME vouchers) for the testing and validation trials of SMEs and start-ups. In this way, Deltares aims to make its knowledge and expertise more accessible to these entrepreneurs. The Deltares strategy for start-ups and scale-ups is to establish links with incubators and accelerators. Agreements to this end have been signed with PortXL and SBIC, for example. A budget of about €700,000 of the institute subsidy has been earmarked for these activities.

	Indicative Budget Euros x 1,000
Moonshot 1 Deltas remain habitable	3,475
Moonshot 2 Hundreds of millions better protected against flooding	2,900
Moonshot 3 Resilient and healthy water resources in 2030	2,600
Moonshot 4 More energy from water and the subsurface	1,050
Moonshot 5 Resilient construction and replacement in 2030	2,400
Knowledge facilities	7,850
Programme Management	662
Total in euros x 1,000	**20,937**

Indicative budget allocation per moonshot, for the Knowledge Facilities and for the Programme Management

	KIA1 E&S	KIA2 AWF	KIA3 H&C	KIA4 S	KIA5 ET	KIA6	Total contribution of KIAs
Moonshot 1 Deltas remain habitable		**					
Moonshot 2 Hundreds of millions better protected against flooding		**					
Moonshot 3 Resilient and healthy water resources in 2030		**	*				
Moonshot 4 More energy from water and the subsurface	**						
Moonshot 5 Resilient construction and replacement in 2030	*	**		*			
Enabling Technologies/ Digital Transformation					**		
Total in euros x 1,000	2,250	8,000	250	250	1,250	0	**12,000**

Indicative budget distribution for strategic research in 2023 at the level of the KIAs (Knowledge and Innovation Agendas) and Deltares moonshots. KIAs 1-6 are Energy Transition & Sustainability, Agriculture Water Food, Health & Care, Safety, Enabling Technologies, and Social Earning Capacity respectively.

Deltares

Appendix A

KIA, missions and MMIPs

Mission		MMIP	Description
KIA AWF (Agriculture, Water and Food supply)	C		Climate-resilient rural and urban area
		C1	Climate- and water-resilient rural areas
		C3	Climate- and water-resilient urban areas
		C4	Improving water quality
KIA AWF	E		Sustainable North Sea, oceans and inland waters
		E1	Sustainable North Sea
		E3	Sustainable rivers, lakes and intertidal areas
KIA AWF	F		The Netherlands is the best protected delta
		F1	Sustainability and cost control in operational water management projects
		F2	Adaptation to accelerated sea level rise and increasing weather extremes
		F3	Netherlands Digital Waterland
		F4	Energy from water
KIA Energy Transition and sustainability	A	1	Renewable energy at sea
	B	4	Sustainable heating and cooling in the built environment
UN Sustainable Development Goals	3		Good health and well-being
	6		Clean water and sanitation
	7		Affordable and clean energy
	9		Industry, innovation and infrastructure
	11		Sustainable Cities and Communities
	13		Climate Action
	14		Life below Water
	15		Life on Land
EU Missions	1		Adaptation to climate change
	3		Restore Oceans and Waters
	4		100 Climate Neutral and Smart Cities
	5		Soil Deal: living labs for Healthy Soils
Sendai Framework for Disaster Reduction	1		Understanding disaster risk
	2		Strengthening disaster risk governance
	3		Investing in disaster risk reduction for resilience
	4		Enhancing disaster preparedness for response and recovery

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Appendix B
Abbreviations

Abbreviation	Dutch	English
ADB		Asian Development Bank
AFDB		African Development Bank
AGWA		Alliance for Global Water Adaptation
APFM		Associated Programme on Flood Management
AWF	Landbouw, Water en Voedsel	Agriculture, Water and Food supply
BOI	Beoordelings- en Ontwerp Instrumentarium	Assessment and Design Instrument Suite
BuZa	Ministerie van Buitenlandse Zaken	Ministry of Foreign Affairs
BZK	Ministerie van Binnenlandse Zaken en Koninkrijksrelaties	Ministry of the Interior and Kingdom Relations
C40		C40 Cities Climate Leadership Group
CEDA		Central Dredging Association
CEN		European Committee for Standardization
CMCC		Centro Euro-Mediterraneo sui Cambiamenti Climatici (IT)
DGWB	Directoraat-generaal Water and Bodem	Directorate-General Water and Subsurface
DHS		Department of Homeland Security (USA)
DPRA	Deltaplan Ruimtelijke Adaptatie	Delta Plan Spatial Adaptation
E&S	Energietransitie en Duurzaamheid	Energy Transition and Sustainability
EA		Environment Agency (UK)
ECMWF		European Centre for Medium-Range Weather Forecasts
ENW	Expertise Netwerk Waterveiligheid	Expertise Network Flood Safety
ESA		European Space Agency
EU	Europese Unie	European Union
EUR	Erasmus Universiteit	Erasmus University Rotterdam
EWEA		European Wind Energy Association
EZK	Ministerie van Economische Zaken en Klimaat	Ministry of Economic Affairs and Climate Policy
FEMA		Federal Emergency Management Agency (USA)
GNS		GNS Science (New Zealand)
HWBP	Hoogwater Beschermingsplan	Flood Protection Programme
HZ	Hogeschool Zeeland	Applied University of Zeeland (NL)
IADB		Inter-American Development Bank
IAHR		International Association for Hydro-Environment Engineering and Research

Abbreviation	Dutch	English
ICOLD		International Commission on Large Dams
IenW	Ministerie van Infrastructuur en Waterstaat	Ministry of Infrastructure and Watermanagement
IHE		IHE Delft Institute for Water Education
IMEC		Interuniversity Microelectronics Centre
INRAE		French National Institute for Agriculture, Food and Environment
IPCC		Intergovernmental Panel on Climate Change
ISSMGE		International Society for Soil Mechanics and Geotechnical Engineering
I-STORM		International network for storm surge barriers
IUCN		International Union for Conservation of Nature
JRC		Joint Research Center of the European Commission
KIA	Kennis en Innovatie Agenda	Knowledge and Innovation Agenda
KICT		Korean Institute of Civil Engineering (SK)
KIM	Kennisinstituut voor Mobiliteitsbeleid	Netherlands Institute for Transport Policy Analysis
KNMI	Koninklijk Nederlands Meteorologisch Instituut	Royal Dutch Meteorological Institute
KWR		KIWA Water Research
LNV	Ministerie van Landbouw, Natuur en Voedselkwaliteit	Ministry of Agriculture, Nature and Food Quality
MMIP	Meerjarige Missiegedreven Innovatie Programmas	Meerjarige Missiegedreven Innovatie Programma's
NBS		Nature-based Solutions
NGI		Norwegian Geotechnical Institute
NIOZ	Nederlands Instituut voor Onderzoek der Zee	Royal Netherlands Institute for Sea Research
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium	Royal Netherlands Aerospace Centre
NSTT		Nederlandse vereniging voor Sleufloze Technieken en Toepassingen
OECD		Organisation for Economic Co-operation and Development
PBL	Planbureau voor de Leefomgeving	Netherlands Environmental Assessment Agency
PIANC		World Association for Waterborne Transport Infrastructure
PIARC		World Road Association
RCN		Resilient Cities Network
RUG	Rijksuniversiteit Groningen	Groningen University

Abbreviation	Dutch	English
RVO	Rijksdienst voor Ondernemend Nederland	Netherlands Enterprise Agency
RWS	Rijkswaterstaat	Rijkswaterstaat (Directorate-General for Public Works and Water Management)
RWS-WVL	Rijkswaterstaat Water, Verkeer en Leefomgeving	Rijkswaterstaat Water Traffic and Environment Services
SDG		Sustainable Development Goals
SITO	Subsidieregeling instituten voor toegepast onderzoek	Subsidy regulations for applied research institutes
SPC		Secretariat of the Pacific Community (Fiji)
STOWA	Stichting Toegepast Onderzoek Waterbeheer	Foundation for Applied Water Research
TNC		The Nature Conservancy (USA)
TNO		Netherlands Applied Research Organisation
TU/e	Technische Universiteit Eindhoven	Eindhoven University of Technology
TUD	Technische Universiteit Delft	Delft University of Technology
USACE		United States Corps of Engineers
USGS		United States Geological Survey
UT	Universiteit Twente	University of Twente
UU	Universiteit Utrecht	Utrecht University
VEI		Vordenbaum Engineering
VU	Vrije Universiteit Amsterdam	Free University of Amsterdam
VU-IVM	Instituut voor Milieuvraagstukken	Institute for Environmental Studies
WB	Wereldbank	World Bank
WEFE		Water, Food, Energy Nexus
WMO		World Meteorological Organization
WUR	Wageningen University & Research	Wageningen University & Research
WWF		World Wildlife Fund

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Deltares is an independent research institute for applied research in the area of water and the subsurface. We work throughout the world on smart solutions for people, environment and society.

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