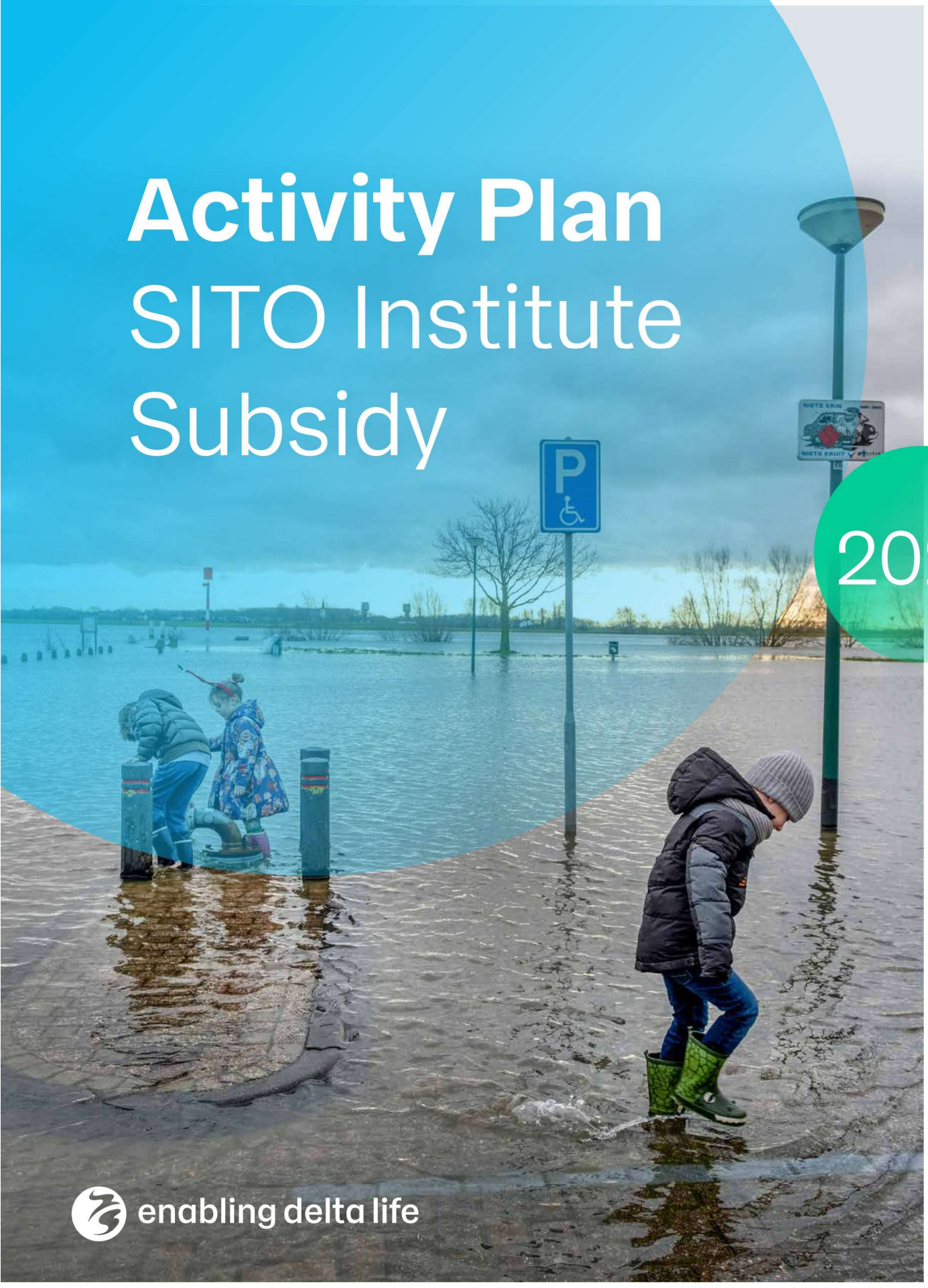
Deltares

Activity Plan SITO Institute Subsidy

2025



enabling delta life

Activity Plan 2025 SITO Institute Subsidy

Table of Contents

1	**Creating more impact with knowledge**	**6**
2	**Liveable deltas in a changing world**	**14**
2.1	Research activities	15
2.1.1	Solution space	16
2.1.2	Dutch delta explorer	17
2.1.3	International Delta assessment toolbox	18
2.1.4	International Delta Platform	19
2.1.5	Societal needs, awareness and stakeholder interaction	20
2.2	Knowledge facilities	21
3	**Making the world safer from flooding**	**24**
3.1	Research activities	25
3.1.1	Integrating topic: flood risk management in urban areas	26
3.1.2	Effective and equitable flood risk management strategies.	27
3.1.3	Quantification of flood hazards, impacts and risks	28
3.1.4	Effective and sustainable reinforcement and management of primary flood defences in the Dutch Delta	29
3.1.5	Preparedness and Recovery: disaster warnings and crisis management	30
3.2	Knowledge facilities	31
4	**Resilient and healthy water and subsurface systems for humans and nature**	**34**
4.1	Research activities	35
4.1.1	Towards zero pollution and healthy environments from source to sea	36
4.1.2	Towards water security for all; availability of sufficient water of adequate quality	36
4.1.3	Adopting holistic system approaches for natural resource management	37
4.1.4	Improving quality of life and environmental health in the built environment	39
4.1.5	Towards stewardship of nature; strengthening biodiversity and habitat diversity	39
4.1.6	Making marine transitions sustainable	40
4.2	Knowledge facilities	41
5	**Energy Transition & Climate Neutrality**	**43**
5.1	Research Activities	45
5.1.1	Sustainable heating and cooling in resilient cities	45
5.1.2	Sustainable electricity generation and transport at large water bodies	46
5.2	Knowledge facilities	49
6	**Resilient infrastructure**	**52**
6.1	Research activities	53
6.1.1	Critical infrastructures	55
6.1.2	Resilience of infrastructure	56
6.1.3	Technologies for data-led predictive asset management	57
6.1.4	Renewal & renovation of hydraulic structures	58
6.1.5	Resilience of port & waterway infrastructure & operations	59
6.1.6	Storm surge barriers	60

6.1.7 Performance of pipeline infrastructures 61
6.1.8 Risk information on piled foundations 61
6.2 Knowledge facilities 62
7 Knowledge facilities 64
7.1 Introduction 64
7.2 Data & data science (digitalisation) 66
7.3 Software 67
7.3.1 Geotechnics and Flood Defenses 68
7.3.2 Hydrology incl. groundwater 69
7.3.3 Hydrodynamics and Morphology 69
7.3.4 Water Operations (FEWS) 70
7.3.5 Water quality and Ecology 70
7.4 Enabling Technologies 71
7.5 Experimental Facilities 73
7.6 Networks and university positions 76
7.6.1 Alliances with universities 76
7.6.2 Networks 77
8 Financial framework 79
8.1 Commitment to mission-driven working 79
8.2 Commitment to collaboration with the private sector 81
Appendix A: Software and Moonshots 83
Appendix B: KIA, missions and MMIPs 85
Appendix C: Abbreviations 87

Deltares

1 Creating more impact with knowledge

The world's delta regions are attractive places to live and work due to their proximity to water. However, they are also vulnerable to natural forces and human activities. Extreme weather events, such as flooding and prolonged droughts, not only disrupt our daily lives but also pose significant threats to infrastructure, agriculture, property and overall well-being. Additionally, the growing global population exerts pressure on available space for housing, infrastructure, agriculture, and natural habitats, reducing biodiversity and effecting both terrestrial and marine ecosystems. To address these issues, global and national agendas, including the Sustainable Development Goals (SDGs), the Sendai Framework, EU and Dutch missions, are guiding collective efforts. These collective efforts catalyse actions across various sectors and stakeholders, fostering a collaborative approach to overcoming these societal challenges.

Enabling Delta Life

Deltares is an independent knowledge institute for applied research, not-for-profit, and statutorily a part of the vital infrastructure of the State of the Netherlands. Deltares as a TO2 institute supports the government in fulfilling its legal duties and addressing complex issues with political and administrative implications. We work across different scales and periods to translate system knowledge into concrete insights and solutions. Thereby we believe in the power of in-depth knowledge from a system-based approach, innovative solutions, and software to keep delta areas, wherever they are in the world, habitable: Enabling Delta Life.

Water and the subsurface form a system, and our choices impact each other. Our understanding of the water and subsurface system plays a crucial role in addressing major societal challenges in the Netherlands, including road infrastructure, river navigation, housing development, the energy transition, nature conservation and preservation, the future of agriculture, and climate adaptation. Globally, disruptions to the subsurface and water systems have an impact on security, peace, and habitability. Healthy water and subsurface systems are therefore key to survival.

Our knowledge is the basis for informed decision-making. The national government holds system responsibility for the public water sector, which partly depends on the knowledge base of Deltares (water authorities, provinces, municipalities, drinking water companies). We consider it our responsibility to identify trends, establish connections between events, and articulate the consequences of decisions, even when they are socially sensitive.

The knowledge of Deltares is indispensable for our governments – from acting upon present day issues and mission-critical events to making the best decisions for the long term. It is up to Deltares to have the knowledge base in order for all the societal issues of today and the future.

Deltares is explicitly positioned as a bridge between fundamental research at universities and its application in the region and by businesses. We follow the 'Dare to share' philosophy: we aim to make access to our knowledge as easy as possible so that it can be widely used. Our knowledge is often applied in the public domain and touches upon the common good. This principle forms the basis for our 'open source' policy.

We work internationally to engage with conditions that are not yet present here, allowing us to expand and validate our knowledge, while also contributing to global challenges with our expertise. We focus on building international networks to strengthen both our position and the Netherlands' global standing in the fields of Delta technology. In addition, cross-border research is crucial for addressing societal issues because challenges do not stop at national borders. Coordinated measures with neighbouring countries can significantly enhance the effectiveness of solutions. Exploring opportunities to innovate and learn from each other is vital. Joint knowledge development with institutions in neighbouring countries supports the justification, acceptance, and commitment to addressing issues and implementing solutions. The increasing importance of international agreements, such as those made by Rhine commissions, is crucial for cross-border climate adaptation.

Mission-driven working

The mission-driven way of working is given focus at Deltares with so-called 'moonshots'. Together, the moonshots form Deltares' strategy, our promise to society to contribute to innovative solutions and significant impact.

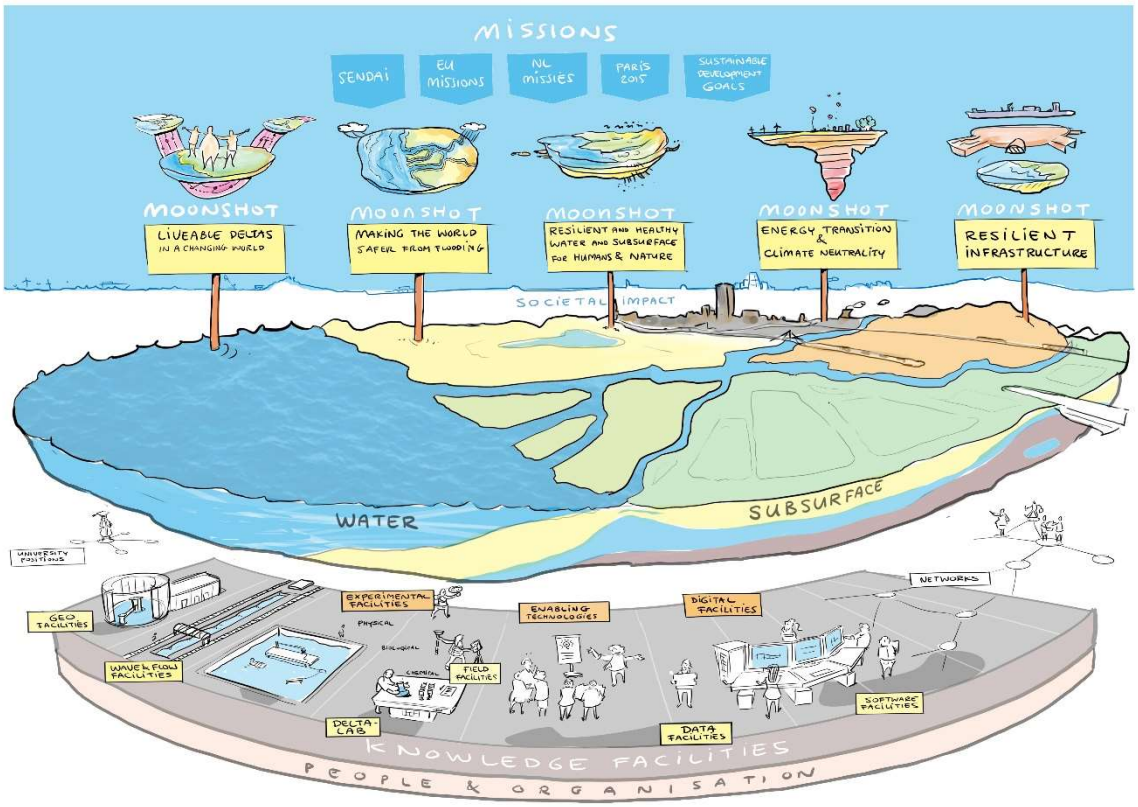


Figure 1.1 - The work of Deltares is mission-driven. From international and national frameworks and missions we derived five long-term goals, our so-called moonshots which together give direction to the Deltares strategy. The water and subsurface is the core of our work at Deltares. Together with our people and knowledge facilities we are striving to make as much impact as possible, enabling Delta Life.

Our moonshots are:

Liveable deltas in a changing world - *This moonshot addresses the critical challenge of how to live sustainably in deltas and ensure a liveable environment for future generations and ecosystems.*

Making the world safer from flooding - *This moonshot addresses how to manage and adapt to flood-related risks.*

Realising resilient and healthy water and subsurface systems for humans and nature -*This moonshot encompasses the transition towards more resilient and healthy water and subsurface systems to improve water availability, (ground)water quality, and biodiversity.*

Energy transition & Climate Neutrality - *This moonshot addresses the goal of achieving climate neutrality and accelerating the energy transition through the responsible use of water and subsurface.*

Resilient infrastructure: Staying connected - *This moonshot addresses the urgent need to develop infrastructure that can adapt to changing societal needs and changing environmental conditions.*

In transition

Deltares is moving away from a traditional supply-driven emphasis on products to a more interdisciplinary knowledge co-creation process involving the whole of society: from governments and citizens, to NGO's and the private sector. It requires new forms of collaboration to get all the different actors working towards aspiring objectives that cannot be achieved individually.

Other institutions are also in transition. Governments have become more entrepreneurial. The private sector has become more sustainably aware. Society has become more (re)active and (dis)informed. The digital revolution is challenging our organization in maintaining our position as technical knowledge provider. Deltares moonshots are a response to this critical moment. We are following and responding to these movements by transitioning our role, contributing in an integrated manner with key (inter)national partners and stakeholders, in connecting our knowledge to overarching societal missions.

How do we create impact?

How do we organize our mission-driven work on these moonshots? We use the Theory of Change (ToC) method, a common practice in working on and structuring impact of (scientific and applied) research. This methodology forms the basis for mission-driven top sectors and innovation policy and is applied by organizations such as NWO, the World Bank and the European Commission.

The ToC method organizes knowledge base, knowledge development, knowledge products, knowledge utilization, and partnerships with a focus on impact (*Figure 1.2*). We use it as a roadmap for making choices, bringing focus and constructive collaboration in our research activities, as well as stakeholder engagement and partnerships. And at the same time, it is a framework for monitoring and evaluating our road to impact. By applying the ToC and addressing these questions we ensure the efficiency of our research processes and relevance of our results, in line with the KPIs for quality and impact that we are assessed on as an applied research institute.

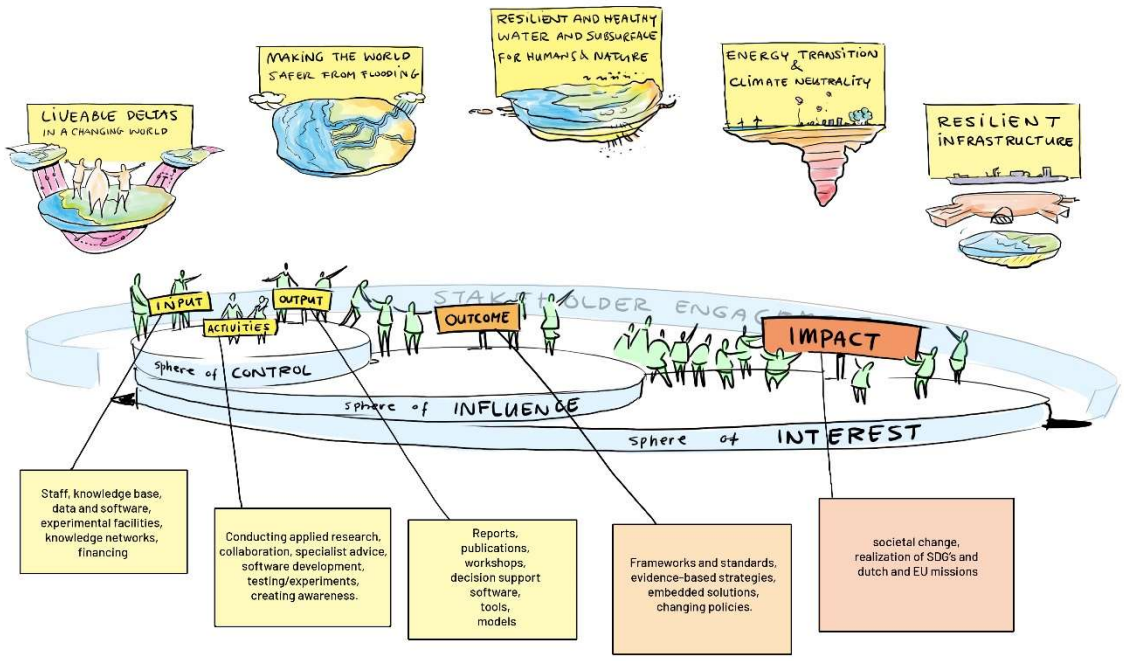


Figure 1.2 – How do you organise your work towards achieving long term societal goals? At Deltares we organized our work along the lines of the Theory of Change framework. We use this framework to bring focus, make choices and make sure we include the right partners along the way, contributing to societal impact. We also use the ToC thinking to constantly monitor the true value of our work in terms of quality, impact and KPI's that we are monitored on as an applied research institute.

Guiding questions[1] in ToC method that we use for programming along these moonshots are:

- How does the future look like in one sentence? (Impact)
- Who must do what differently to achieve transformation? (Outcome)
- What is the tangible result that contributes to change? (Output)
- What do you need? What can you do to achieve the required change? (Activities/Input)

By addressing these questions onto our research, tools, approaches, and partnerships we can identify activities through which we can most impactfully contribute to the mission of enabling delta life.

Through co-creation with universities, private and public partners we ensure our projects are scientifically groundbreaking, directly applicable, and valuable to society. Our focus is on delivering measurable results, always striving for the highest standards of quality and integrity.

We achieve this through monitoring via an impact and quality framework along the TOC and by considering recommendations such as those from EMTO 2020, advisory boards, and collaboration partners. We strive for reliable and transparent knowledge outcomes. Therefore, we systematically monitor our work on impact and quality through interim

[1] These questions are derived from the ToC game developed by Erasmus University.

evaluations, moonshot portfolio management, and stakeholder consultations and number of publications in peer-reviewed journals.

Ensuring the quality of our digital facilities is especially important to us in light of rapid digitization and major technological developments such as AI. We continuously invest in advanced technologies and maintain strict quality standards. We focus on the development of unique modeling tools and data analysis systems, which are essential for accurate scientific research and innovative solutions. Key areas include applying the FAIR data principle and regular software updates for optimal security and efficiency. In this way, we remain a leader in our domain, with substantial scientific output contributing to solving current societal issues.

Developments are happening quickly, and the world is becoming more complex. This requires constant vigilance and critical monitoring, because we do not want to compromise the quality of our knowledge.

Knowledge base Deltares

One important element of our knowledge base is the expertise of the Deltares crowd. We have over 900 highly qualified employees, representing over 60 nationalities, who are curious and driven.

Deltares possesses a broad spectrum of expertise, ranging from civil engineering, such as geotechnical and hydraulic engineering and water management, as well as earth sciences, environmental engineering, hydrology, applied mathematics, physics, biology, ecology and geosciences/geophysics, data science, and software engineering. We also have highly specialized employees working in social sciences, with knowledge ranging from governance to economics and legal to process and transition knowledge.

Our knowledge facilities, like our experimental facilities and software, are another fundamental part of the knowledge base. In our facilities, the knowledge and learnings of our experts are validated and converted into usable tools and models, to support and assist policymakers and decision-makers at governments, Rijkswaterstaat, water authorities and companies. Examples include flood and drought warning systems, models showing the amount of groundwater, river discharge or subsurface stability, software for performance monitoring of engineering or hydraulic structures and visualisations of the effects of drought, flow, and sediment transport.

Our unique and for The Netherlands vital experimental facilities are an integral part of our knowledge base. We test our knowledge, calculations, and solutions in these experimental facilities, such as wave flumes and basins, laboratory, scale models or the Geocentrifuge. These are indispensable for arriving at workable, scalable, and evidence-based solutions.

Partners in mission-driven work

We can only achieve our mission by working together with other (knowledge) partners and our clients.

Deltares is part of a broader knowledge ecosystem. Regarding our activities and output we constantly evaluate, develop, and seek new opportunities for research together with our partners to contribute to make societal impact. Our partners in mission-driven work and research are for example other TO2 organisations as TNO, WUR and Marin, and national

and international knowledge institutions, like (applied) universities, or stakeholders with whom we conduct our research.

We work towards outcome for the national government and other public and private parties in various collaborative relationships, both domestically and internationally. Important ministries we work with are (the different departments within) the ministries of Infrastructuur en Waterstaat, Economische Zaken, Binnenlandse Zaken en Koninkrijksrelaties, Volkshuisvesting en Ruimtelijke Ordening, Landbouw, Visserij, Voedselzekerheid en Natuur en Klimaat en Groene Groei.

ProRail, Rijkswaterstaat, building and dredging companies, harbours and the water authorities are among our partners in realising outcome in water safety and reliable infrastructure. For healthy drinking water and to fight salinisation we work with drinking water companies, farmers and health organisations. Energy companies, offshore wind and solar energy developers, municipalities and nature organisations team up with Deltares and other knowledge institutions to speed up the energy transition. For every mission we work on, we attract and engage all kinds of private companies, from start-ups to small and big companies. This ensures our tools, models and solutions are fit for the outside world. EcoShape – Building with Nature is a network of organizations and individuals, with which we work together to advance the application of Building with Nature in water related societal issues

Activity plan 2025

Working mission-driven to achieve five ambitious goals with significant impact is not easily done. Each year, we further streamline our activities along these goals. In programming our activity for the SITO Institute Subsidy (SITO IS) we are going through a transformation. Where we tried to plot all our activities of Deltares under one of the five moonshots last year, we now put more focus on choosing selectively and more strategically from the line of our moonshots. This year we also put effort into strengthening the relation between moonshots and the programming of our knowledge facilities. It helps us to make deliberate choices regarding the deployment of people and resources.

Of course, as Deltares we want to build upon our existing knowledge base. Thereby we are constantly finding the balance between maintaining the current knowledge base and facilities and taking position in identifying trends or new developments that need attention to make future impact and further enhance our quality.

In this submission for SITO IS of activities for Deltares 2025 we thus focus on activities that contribute to the five moonshots impacts that each are built around several societal missions. In the following chapters we discuss these activities along the ToC methodology for the different moonshots. These moonshot chapters are followed by a chapter on our knowledge facilities and a chapter on financials.

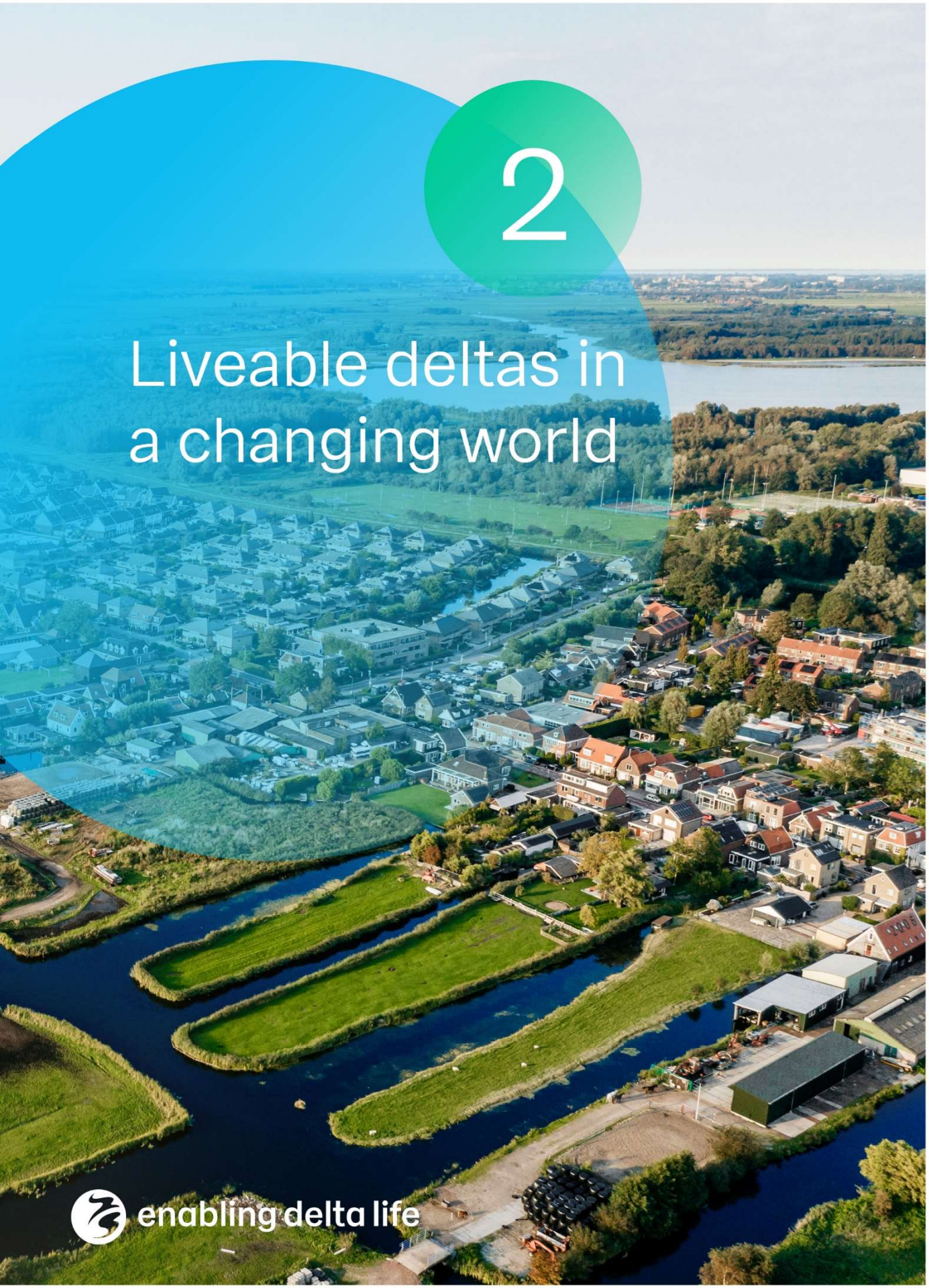
In moonshot chapters firstly the envisioned impact, goals and role of Deltares will be addressed in the light of societal challenges specifically in that moonshot field. Then the 2025 proposed research lines with activities will be discussed which lead to the output that will support the outcome needed to create that societal impact for that moonshot. For each moonshot research lines are selected and formed with great attention for a desired level of impact and quality that fits the standards of Deltares.

The activities proposed per moonshots in this submission are part of a greater portfolio of Deltares projects that comprise SITO program subsidy projects, European projects, market projects and TKI collaborative projects, etc.

This draft activity plan sketches the outline of the mission-driven Strategic Research that Deltares will conduct in 2025 with the SITO institute subsidy. The strategic research activities are strongly entwined with many of our other activities: our applied research programs with ministries (SITO Program Subsidy), partnerships with private partners and knowledge institutes in the context of the Dutch top sectors (TKI projects), international consortia (EU project, etc.). Achieving societal goals is only possible through close collaboration with our key stakeholders and partners. Therefore, we will seek alignment more frequently and at earlier stages to make joint decisions in projects, such as those within the EU and TKI frameworks. Shared commitment and investment lead to more effective goal attainment.

Towards an effective and synergetic activity program for 2025!

Deltares



2 Liveable deltas in a changing world

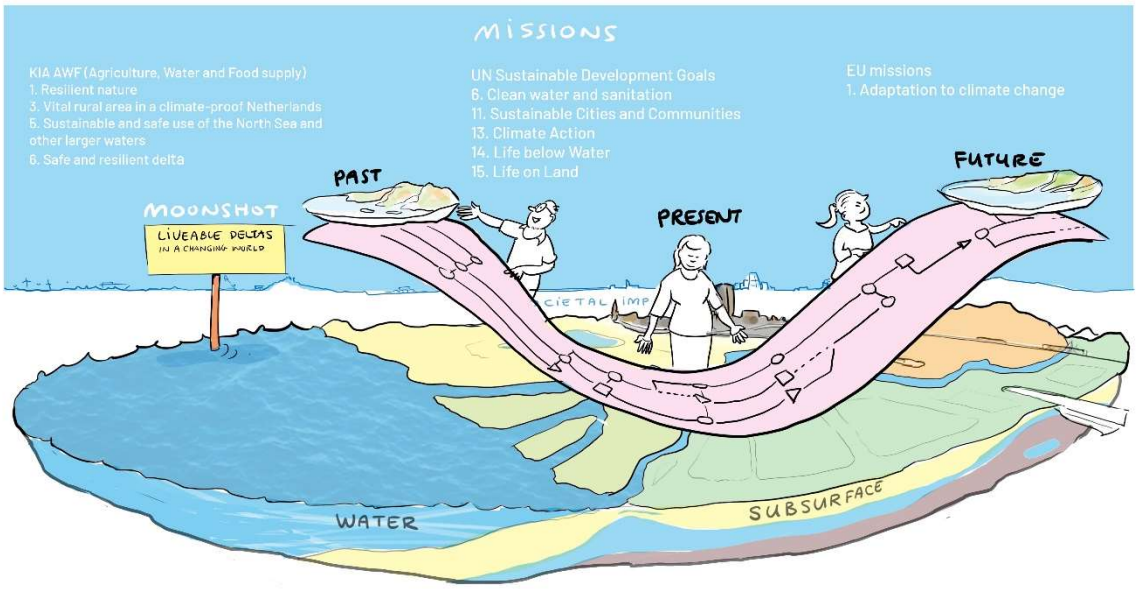


Figure 2.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the moonshot: Liveable deltas in a changing world.

River basins, deltas and coastal areas[2] are attractive places to live and are important socio-economic hubs. At the same time, they are hotspots of climate change impacts and adaptation, as well as economic and social developments, ecosystem degradation and climate mitigation. Climate change impacts are already happening, biodiversity is declining, and various societal, economic and infrastructure investments decisions have to be anticipated in the next decades. Therefore, now is the imperative moment to rethink human activities and reimagine future deltas, their upstream areas, and coastal areas.

This moonshot addresses the critical challenge of how to live sustainably in deltas and ensure a liveable environment for *future* generations and ecosystems. We envision deltas where inhabitants are safe from flooding and assured of clean fresh water even in periods of shortage due to droughts. This is all in a just and equitable way, and where natural resources, particularly water and subsurface, are used and managed in a way that ensures their enduring value. Within these deltas, nature is protected and supported in adaptation to climate change and other impacts, and society is motivated and dedicated to fostering a liveable and sustainable future for the delta.

Deltares, together with its partners, offers credible and reliable future pathways for living sustainably in delta's worldwide with a focus on water, and subsurface systems. We support policy makers and stakeholders to develop long-term strategies that guide near term decisions and measures based on science and practical experience. We develop methods and tools to qualitatively and quantitatively show the effectiveness and feasibilities of these

[2] Hereinafter collectively referred to as deltas

strategies and measures. We create awareness to policy makers, stakeholders and civil society on the need to rethink their delta in a changing world (climate change, societal transitions, human behaviour, subsidence etc.).

The distinction of this moonshot compared to the following four moonshots is its emphasis to long-term (decades to century) strategies and adaptive planning in an uncertain future, which implies back casting, spatially integrating measures and developments on different spatial and time scales. The latter in close cooperation with the other moonshots.

Outcome 1: Policy makers and stakeholders design long-term policies that guide near-term decisions (outcome). Based on credible and reliable solution space, adaptive pathways and strategic plans developed by Deltares and partners (output).

Outcome 2: Informed decision making on adaptation strategies for long-term processes and resilient development in deltas and coasts including the cities and rural areas therein. Based on the scientific knowledge base provided by Deltares and partners (output).

Outcome 3: Society uses Deltares output and is aware and supportive of the need to rethink living in deltas in a changing world.

2.1 Research activities

We have defined five large overall outputs (deliverables (Figure 2.2)) that support one or more outcomes and makes an impact. These deliverables have their foundation in the expert knowledge of the water and subsurface system. Several activities (subtasks) are carried out, that together create the desired overall output.

We aim to provide insight in the **Solution space** [1]. This deliverable contributes to Outcome 1 in particular. For quantitative substantiation of the solution space we need **The Dutch delta explorer** [2] and **The International delta assessment toolbox** [3], which contribute to the knowledge base of Outcome 2. **The International Delta Platform** [4] provides data for the International delta assessment toolbox (Outcome 2) and creates insights, understanding and awareness (Outcome 3). The societal foundation of all large deliverables is organized in the **Societal needs, awareness and stakeholder interaction** [5], where partnerships and knowledge development priorities are set-up from societal perspective and tools are developed for co-creation and awareness. This deliverable contributes to Outcome 3 in particular. The Activity plan has a national and international focus: large deliverable 2 links to the Dutch Delta, 3 and 4 link to international deltas and 1 and 5 cover both.

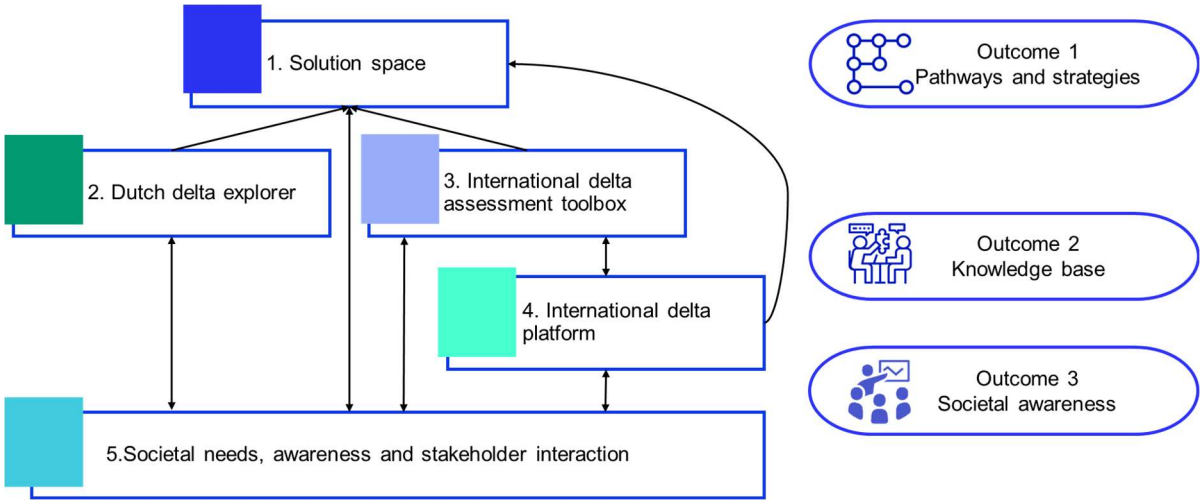


Figure 2.2 – The large deliverables.

For each large deliverable we describe the **objective**, the activities funded by **SITO-IS** in 2025, examples of the **portfolio** funded by other resources and the contribution of the large deliverable to the **outcomes** of the Moonshot.

2.1.1 Solution space

The **objective** of the large deliverable Solution space is to develop tools and methods for generating, evaluating, and visualizing strategies and pathways, integrating early warning signals and aligning with (among others) spatial developments, infrastructure maintenance, nature restoration, and climate mitigation. This work builds on the DAPP (Dynamic Adaptation Policy Pathways) method, transition theory, and visioning techniques. Involving stakeholders from different disciplines is also paramount to identify and prioritize these values. The aim is furthermore to focus on creating long-term adaptation measures and strategies, assessing the effectiveness and feasibility of risk reduction measures and integrating them into the DAPP analyses to develop climate-resilient strategies. In cooperation with large deliverable 5, we want to strengthen the science-policy interface by co-creating and sharing knowledge, ensuring our research is both scientifically robust and practically applicable.

We work on **SITO-IS activities** within three themes:

1. *Expand the DAPP method*. Examples of activities include connecting long-term vision with DAPP, allowing backcasting and forecasting, including spatial analyses and adaptation signals, interactions between different pathways, just and equitable adaptation pathways, taking into account different developments, expanding the Pathways generator to generate and evaluate pathways and strengthen the tipping point analyses.
2. *Adaptation measures, strategies and climate-resilient strategies.* We work on building blocks contributing to long-term adaptation strategies and visions and insights in what works and what doesn't work for long-term adaptation.
3. *Education and knowledge dissemination*. We establish our strong collaboration with stakeholders (international – related to the focus areas, national and regional). We continue contributing to education and will produce peer-reviewed papers.

In 2025 we continue to support the research developments in the projects DeltaWealth, desirMED, MYRIAD-EU, REACHOUT EU Green Deal 9.2, NL2120 – The Green Earning Potential, Physical Solution Space deltas worldwide and Future FRM Tech.
Within the **portfolio** we test, apply, improve and broaden this large deliverable by for example applying the DAPP methodology in regions in the Netherlands (Dutch and EU projects), by further developing the global international Pathways approach, Flood-resilient Landscapes and applying the method of global hackathon design in international cases. In this manner the ideas that form the basis of DAPP will be more available to non-technical stakeholders and support better policy decisions by envisioning decision chains and integrating them with physical changes (example: Delta Program). One of the existing challenges of our stakeholders is how to keep their options for decision making open, but at the same time know how all the different elements of the system will change so that they can make well-informed and timely decisions on for example infrastructure projects or nature restoration.
Outputs from the large deliverable Solution space for **outcome 1** include tools to generate and evaluate strategies, methods to (spatially) integrate multiple transitions and early warning signals. This large deliverable also contributes to **outcome 2** with methods for analysing compounding and cascading effects. Additionally, the deliverable supports the assessment of the effectiveness and physical feasibility of adaptation strategies and pathways. Sharing knowledge, tools, experiences and peer-reviewed papers allows society to reimagine and move towards sustainability for outcome 3.

2.1.2 Dutch delta explorer

There are several communities and projects working on new designs of the Delta. However, a quantified evaluation of the feasibility and effectiveness of these designs – including the strategy towards the design – is missing and is important input for large deliverable 1 (Solution space). Existing tools are not able to quantify these strategies in an integrated and fast way.
The **objective** of the large deliverable Dutch delta explorer is to develop a comprehensive national-scale model that assesses the development of the Dutch Delta under a range of climate and socio-economic scenarios and how this may be influenced by human interventions. The main new element of this explorer is that it integrates quantitative information on the Dutch delta, including the effects of human activities, and provides a basis and substantiation for new designs. This model will adopt an integrated approach addressing flood risk, freshwater availability and biodiversity and will build on the expert knowledge of i.e. hydrology, ecology and coastal dynamics by incorporating the latest system knowledge. The model integrates these different elements into one model that is easily accessible to users. Additionally, “score cards” will be created to evaluate the costs and impacts on other functions like shipping, recreation, spatial planning etc. The model focuses on the primary water system (hoofdwatersysteem) and interventions that have an impact on a relatively large scale. Implementing these human interventions into the deltas’ design will necessitate adjustments to existing models. Simplifications are crucial to achieving the objectives without compromising the model's accuracy. This integrated approach will facilitate the examination of long-term scenarios, ensuring that the model remains a valuable tool for decision-makers in safeguarding the Dutch Delta's future.

Building on the 2024 activities lessons learned (successes and failures of models from the past), community building, stakeholder needs, model design, we aim for these **SITO-IS activities**:

- Further clarifying the need for the integrated model by identifying specific requirements and expected outcomes, including time and spatial scales.
- Making an inventory of existing 'sub models' (or building blocks) and evaluate the suitability for uptake in an integrated model.
- Making a prototype to illustrate the potential value for different types of users.
- Developing a long-term plan with stakeholders and potential partners and exploring ways to finance the further development of the model.

Within the **portfolio** the following output (tools, knowledge, needs) of existing projects will contribute to the Dutch Delta Explorer.

- Detailed mono- and multi-disciplinary models that simulate the future water and subsurface conditions of the Dutch Delta, for example within SITO-PS projects related to salinisation, land subsidence, water quality, flooding, drought.
- Quantitative long-term evaluations of the delta, including tipping point analyses (infrastructure, available resources, economics, …).
- Co-creating on long-term outlooks for the Netherlands including Knowledge program on sea level rise (SITO-PS), Redesigning Deltas, Flood Resilient landscapes.
- Working on technical tooling to run large scale flexible models, such as AI techniques, parallel computing, flexible mesh.

By offering a scientific knowledge base firmly rooted in our disciplinary knowledge of water and subsurface and evaluating a wide range of scenarios and human interventions, the model will enable informed decision-making on adaptation strategies and directly supports **Outcome 2.** By demonstrating the feasibility and effectiveness of different delta management strategies, the model can help society understand the importance of rethinking how we live in deltas in changing environmental and socio-economic conditions, which nicely contributes to **Outcome 3**. In addition, by providing a comprehensive analysis of the Dutch Delta under various scenarios, the model will contribute directly to large deliverable 1 and therefore indirectly support **Outcome 1**.

2.1.3 International Delta assessment toolbox

Crucial to the decision making are the quantifications of the long-term dynamics of the water and subsurface system, the impacts (e.g. flood hazard, water availability, ecology and transport) and available measures to mitigate adverse long-term impacts. The **objective** of the large deliverable International delta assessment toolbox is to develop a set of tools and guidelines, focusing on water and subsurface, that facilitate assessments of long-term delta developments under a range of scenarios and human interventions all over the world. We want to create new and improved bio-physical process models, building further on incorporating the existing system knowledge, as well as tools for socio-economic impact assessment. Furthermore, we aim to expand our existing tools and methods to assess the effect of measures. Finally, we want to improve the workflows to connect the various components of such impact assessments: data, climate- and socio-economic scenarios,

biophysical models, hazard-, impact- and risk assessment models and adaptive pathways tools.
The role of Deltares is to further develop the tools and to (help) apply these in long-term planning projects for delta's, coastal systems, river catchments, (mega-)cities etc. The tools will be developed in co-creation with internal and external stakeholders to make sure they meet the needs of these stakeholders. For the coming years we foresee the following **SITO-IS activities**:

- Setting up a generic and modular approach for socio-economic impact assessments. We continue our work on impact tools such as FIAT, we make tools developed for specific projects more generically applicable and we develop tools/models for socio-economic impacts that are not available yet.
- Developing a framework for multi-hazard assessment. We improve multi-hazard assessments by making them more coherent, by filling knowledge and information gaps and by validation in real-life cases within other parts of the portfolio.
- Developing and implementing improved models such as dynamics of sandy and muddy coasts (Shoreline M/S) and an integrated groundwater-salinization model. These dynamics are relevant for long-term changes and feasibility of strategies.
- Implementing several socio-economic impact modules related to drought (in collaboration with moonshot 3), heat and flooding (in collaboration with Moonshot 2).
- Implementing new complete hazard-impact workflows in prototype software.
- Applying the tool-set on a large case study (Mekong delta) for test and demonstration purposes.
- In 2025 we continue to support the research developments in NL2120 NBS, NOW-ParCA, RESHAPE, WadSed2, Future FRM Tech, MYRIAD-EU, NWA-ORC Red and Blue, UP2030 Enabling city transitions through innovative urban planning and design, DeltaWealth and NWO VICI Deltas out of shape.

Activities in the **portfolio** include connecting models for freshwater availability, flood risk management, coastal dynamics, land subsidence, adaptation tools such as Flood Adapt, Drought Adapt, impact assessments including equity and other socio-economic aspects, international adaptation projects and world scale modelling. This is in collaboration with key organizations, for example Vietnamese, Colombian and Indonesian ministries, WWF, WB, ADB, AFD, GIZ, RVO, PfW, Vitens-Evides international alongside academic institutions.

This deliverable contributes to **outcome 2** by providing a better understanding of compounding and cascading effects and the interaction and co-evolution of these delta system processes with societal developments, ecosystem degradation and change and biodiversity loss. This deliverable contributes to **outcome 1** as well by informing the need for adaptation with quantified and reliable pathways based on long-term dynamics of the water and subsurface system and offering the quantifications needed for large deliverable 1.

2.1.4 International Delta Platform

The **objective** of this deliverable is to identify hotspots that require climate adaptation measures as well as create awareness on present and future geophysical changes impacting deltas. We do this by building an accessible, up to date platform for internal and external technical users and visualizing the translation of climate projections to impacts and risks up

to the year 2100 all over the world. Furthermore, we foresee that with this platform, that has a strong interaction with the information from the International delta assessment toolbox (large deliverable 3) regular reports on the state of the delta will be created which share state-of-the-art knowledge on historic, present and future trends on water and subsoil related themes. The data that is shared through the platform itself is based largely on existing datasets but the way in which users can interact with the data and how data is visualized is novel.

Within this deliverable we will work on **SITO-IS activities** such as creating a cloud-based, passive repository that allows direct access to data sets (building maps, shorelines, elevation model, bathymetry, GDP, floodmaps, subsidence and sea level projections AR6) and products (Repository, Workbench (API), Dashboard, State of the Delta reports and Viewer). We also aim to create an online coupling to a GitHub workbench to perform data analysis in the cloud. We will work on creating a viewer so that users can interactively inspect data of a region of interest. For the State of the Delta reports, we will use data, AI, and DeltaChat, depending on the requirements from the end-user group. Depending on their wishes we foresee for example projections on erosion, flood risk or freshwater availability. In 2025 we continue to support the research developments linked to this deliverable, for example, in the European project REACHOUT.

We are involved in a range of associated projects in the **portfolio** such as Blue Earth Data, European projects such as CoCliCo and REST COAST and projects for the Dutch government like IPDC. For this deliverable we foresee collaboration with international stakeholders and networks, including the IPCC, GWP, JRC, EEA, WB, WMO, Source2Sea and WaL (Water as Leverage). The coming year we have the ambition to collaborate and specifically interact with countries that have a connection to the Dutch government and/or where we are looking to expand our portfolio (i.e. Surinam, Indonesia, Ghana, Mekong Delta, Egypt, Colombia, Egypt) on this topic. We will start with internal clients (proofs of concepts) in 2024/2025, after which we will extend to specific external collaborators based on ongoing networks, projects and the future Deltares international strategy.

With the information on delta's typically being widespread and frequently updated and the need of our stakeholders for region-specific measures, the international delta platform contributes to **outcome 2** by providing integrated, state-of-the-art information through a data platform. With this deliverable the vast and rapidly expanding data on the physical system is translated into accessible storylines and visualizations to support decision-makers (outcome 1), feeding the societal debate on how to live sustainably in delta's worldwide (outcome 3).

2.1.5 Societal needs, awareness and stakeholder interaction

For Deltares to contribute to the expected outcome and impact it is important to really understand the underlying mechanisms for change in different parts of the world from a societal and institutional perspective. Stakeholder interaction is key to obtain this knowledge, for all the large deliverables in this moonshot. The **objective** of the large deliverable Stakeholder interaction and awareness methods is twofold. One objective is to create a portfolio of methods that will support the collaborative exploration of plausible future delta states and the development of adaptation pathways. The second objective is to identify current practices and institutions and how information is used, identify the societal needs and

provide input to the other large deliverables. The methods will be designed to engage stakeholders in meaningful ways, including participation, understanding their needs and concerns, building consensus, and enhancing decision-making processes with increased transparency and accountability. The portfolio will include various tools and methods, such as interactive modelling tools, augmented and virtual reality interfaces, board games and serious games. These will be adaptable to different stages of planning and assessment, addressing the needs of stakeholders with diverse knowledge levels. The tools and methods will be used – and where possible designed - in collaboration with stakeholders, ensuring that both social and scientific learning objectives are achieved.

SITO-IS Activities include:

- Moonshot ambition for stakeholder interaction and awareness tools at Deltares and within partnerships.
- Elaborate existing tools and methods in collaboration with partners.
- Develop new tool and methods concepts and prototypes with partners.
- Elaborate on and application of social science methods to understand the policy making and societal system and the assessment of societal needs, as part of the selected case study and in line with other activities.
- Elaborate on concepts such as scaling, policy implementation, dealing with uncertainty in policy making and cross-sectoral policy and decision-making.
- Continuation of the project OR ELSE with a Digital Twin for sand mining on the North Sea.

Examples of tools within the current **portfolio** are SLR retreat game, *Tastbaar Landschap,* Virtual River Game, Sandbox-FM, Water Warden, Virtual Climate Lab, Sustainable Delta SG, Digital Twins for Sand Mining, Port of the Future, Circle and Mekong GW game. Not all these tools are directly related to the Moonshot, but we can use the lessons learned and building blocks already developed.
Engaging stakeholders through the development and refinement of interactive tools will contribute to all three outcomes. For outcome 1 this will be focused on increasing the societal and institutional credibility and reliability of the output of the large deliverables of moonshot 1. Secondly it will contribute to outcome 2 by getting insight in the societal and institutional change processes that informed decisions need to feed into. Finally, this large deliverable will directly contribute to **outcome 3**, by increasing societal awareness and support for sustainable living in deltas. This large deliverable will support policy makers and stakeholders in the societal debate for liveable deltas by being able to make knowledge accessible and translate insights into societal urgency and understanding. Additionally, the tools and serious games will indirectly support Outcome 1 by providing actionable adaptive pathways and strategic plans for policymakers and stakeholders.

2.2 Knowledge facilities

The knowledge facilities in terms of enabling technologies, data and software as well as the experimental facilities provide the technical foundation for the Moonshot. Challenges we face within this Moonshot are that our tools need to be able to integrate different models, simulate a long time period with a changing future and create meaningful output that is user friendly,

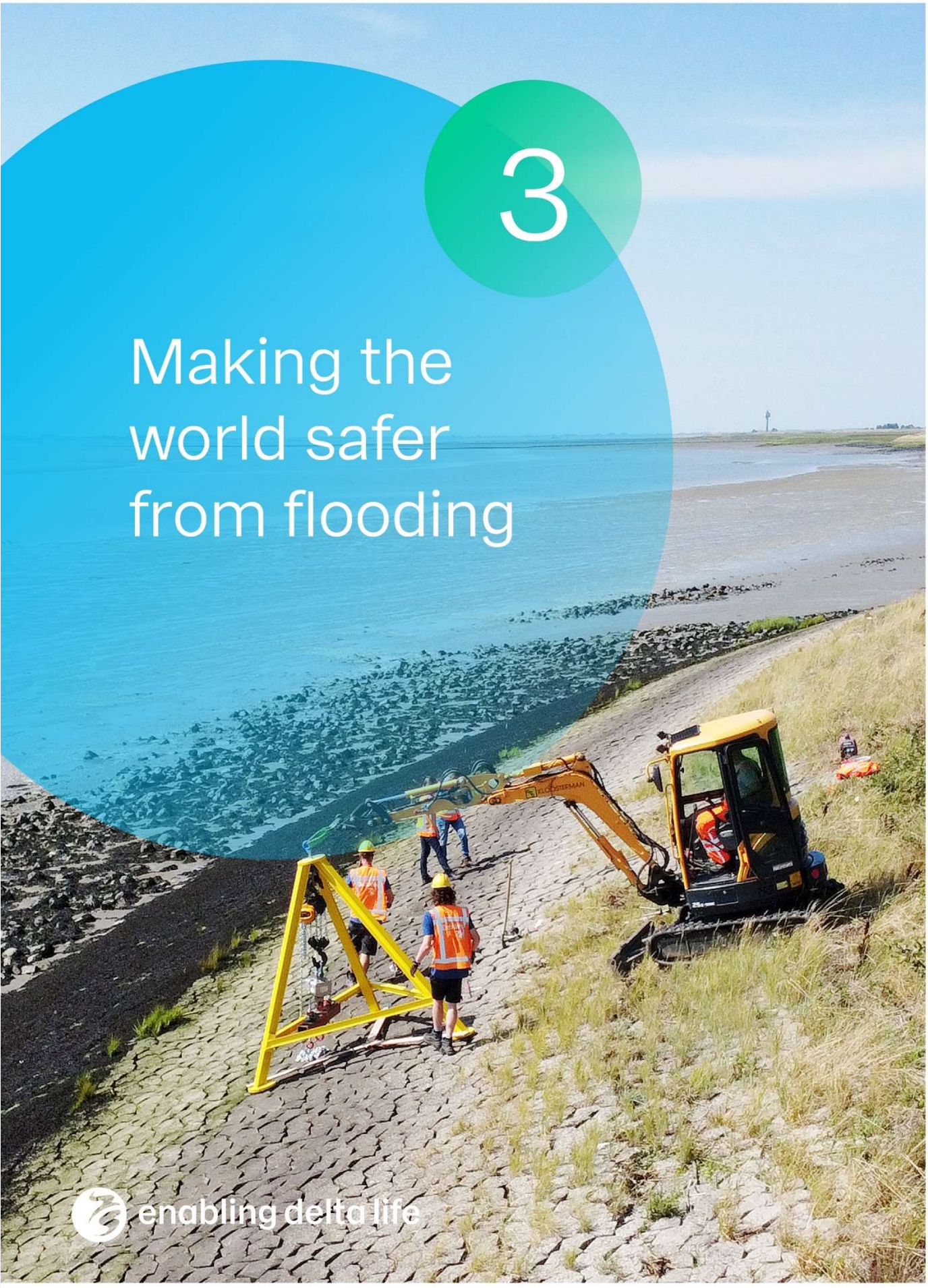
interactive and can be obtained within limited computation time. Quantifying the effect of measures is another challenge. Solving these challenges is an ongoing process, and hence, will never be truly ‘solved’. Deltares is continuing to work on these challenges.

The interaction of this Moonshot with the Knowledge facilities is described in further detail in chapter 7. More detail about the connection between the Product lines and the Moonshot can be found in chapter 7.3 and Appendix A. The Moonshot cooperates with Enabling technologies (chapter 7.4) on applying new technologies (AI, LLM, agent based modelling) to concrete cases and investigate their contribution to the Moonshot large deliverables and outcomes.

Deltares

3

Making the world safer from flooding



enabling delta life

3 Making the world safer from flooding

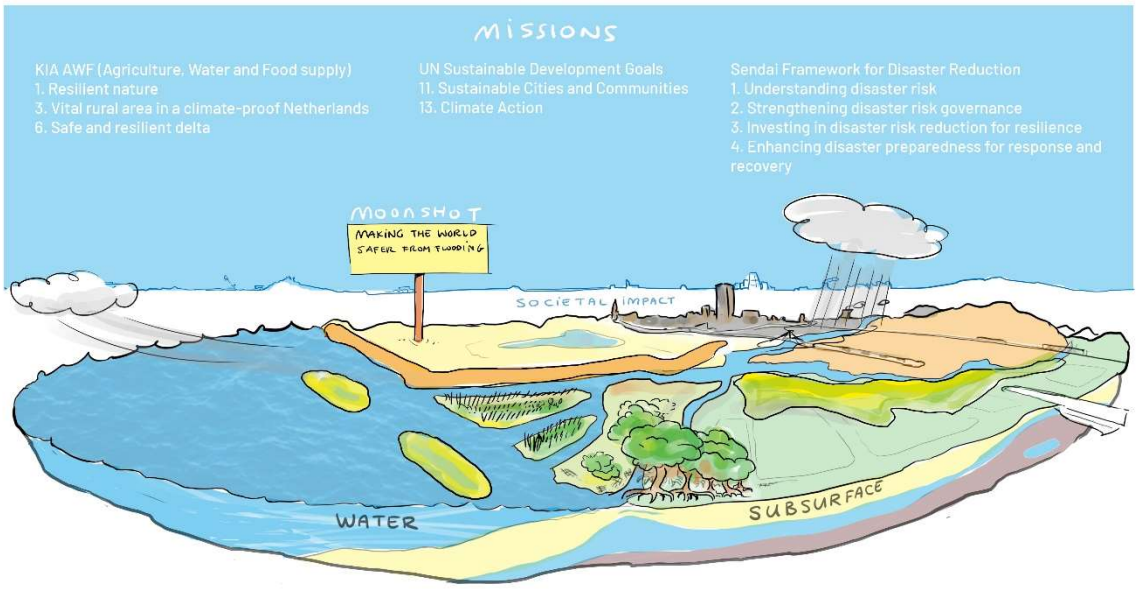


Figure 3.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the moonshot: Making the world safer from flooding.

Floods and water-related hazards are an important threat to global well-being and economic development[3]. Flooding results in casualties and other health and well-being impacts, as well as extensive damages to homes, infrastructure, businesses and natural environments. Floods also disproportionally affect socially vulnerable groups and people in vulnerable low-lying areas, causing and sustaining inequities in societies. The frequency and intensity of floods are expected to increase due to climate change and related changes to hydroclimatic systems, more intense rainfall, and sea level rise. At the same time, populations and infrastructural investments in flood-prone areas are increasing, especially in urban areas, leading to greater exposure of people and assets and increasing competition for land use. This means flood risk management is a continuing task, which will become increasingly difficult over time. By enhancing knowledge on floods, flood risks and solutions this moonshot enables societies to develop and flourish.

To enable a country and a world that is safer from flooding, the goal of this moonshot is that: The Netherlands (including the overseas municipalities) and other countries can manage and adapt to flood-related risks through a Flood Risk Management strategy combining prevention, mitigation, preparedness and response measures so that current and future generations and society can thrive in an efficient, sustainable and equitable way.

[3] https://www3.weforum.org/docs/WEF_Global_Risks_Report_2023.pdf

Primarily, these are the following outcomes:

- Regulations and Laws that enable governmental and societal actors to realize flood risk management in a sustainable and equitable way.
- International governments implement whole-of-government efforts leading to whole-of society approaches to flood risk management.
- Evidence-based, timely and contextualized political decisions on flood resilience protection measures and investments.

that are built on:

- Well-trained and informed staff at FRM and spatial planning agencies and at national governments, IFIs and consultants.
- Understanding by different stakeholders (government, business, academia, NGO) of their role in practice, advice and research in FRM.
- Well-informed and strengthened networks with key supra-national institutions (WB, IPDC, CDRI, etc.) working on flooding.
- Shared narrative with national and regional authorities.

Deltares delivers the following output: reliable, accessible, understandable and actionable flood risk information and failure probabilities and information on effective adaptation and mitigation strategies.

3.1 Research activities

To reach the objectives of this moonshot, we need to understand and quantify the physical processes resulting in floods and concurrent hazards and flood impacts and have knowledge about measures that prevent or mitigate floods and their impacts, be able to forecast flooding events, and foremost bring all these elements together in flood risk management strategies. Therefore, we have structured our research efforts around the Disaster Risk Management (DRM) Cycle (Figure 3.2) in four research lines leading up to the Deltares output for this moonshot:

1. **Effective and equitable flood risk management strategies:** Develop effective, equitable and sustainable flood risk management strategies for flood-prone areas which encompass all phases of the DRM cycle in an integrated way.
2. **Quantification of flood hazards, impacts and risks:** Obtain better knowledge and quantification of the physical processes that contribute to flooding and concurrent hazards in our current and near future climates, and develop methods to quantify impacts.
3. **Prevention and mitigation: Effective and sustainable reinforcement and management of primary flood defences in the Dutch Delta:** Develop and maintain knowledge related to primary flood defences which contributes to the HWBP (High Water Protection Plan) goals, improvement of inspections and maintenance, and asset management (Zorgplicht and Kustlijnzorg).
4. **Preparedness and Recovery: Flood forecasting, disaster warnings and crisis management.** Enable flood forecasting and early warnings to reduce the exposure and vulnerability of people to flooding (linked to both the Preparedness and the Recovery phase of the DRM cycle).

The four lines are complemented with an integrating line on urban flooding.

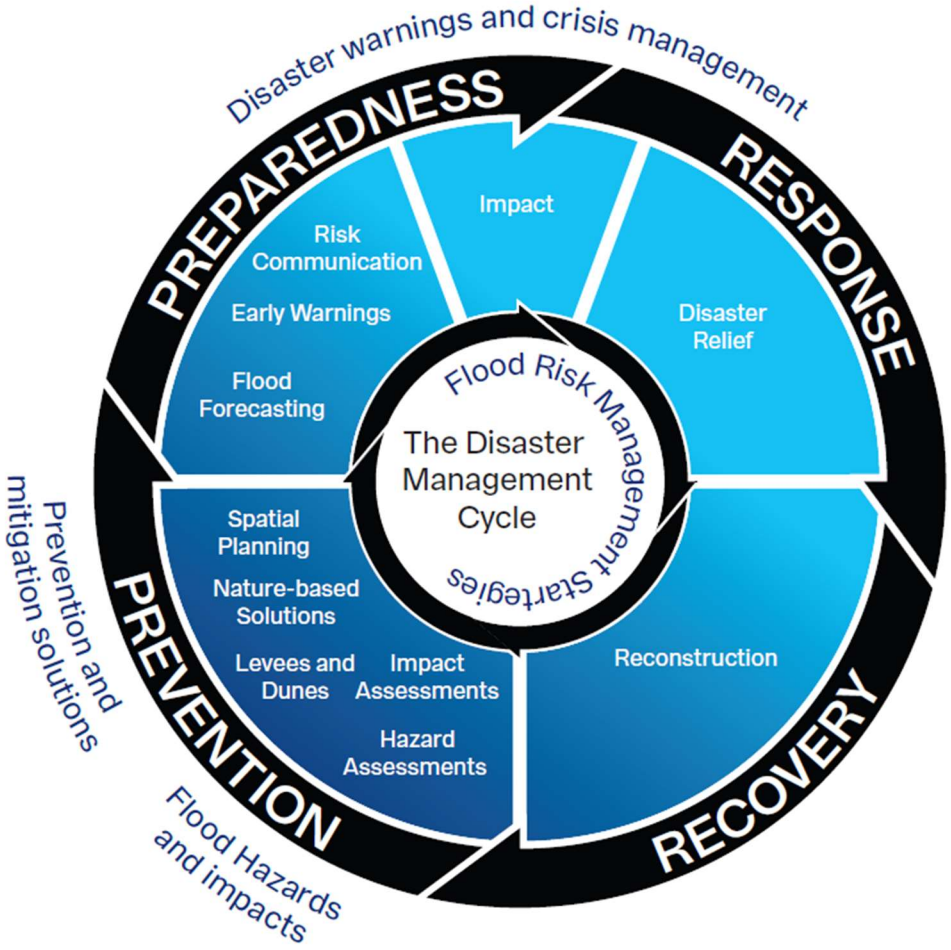


Figure 3.2 - The Disaster Management Cycle, describing four phases. In the Prevention stage, risks are identified, and structural measures are implemented to reduce flood risks. In the Preparedness stage, early warning systems and evacuation plans are made to deal with an impending disaster. The Response phase deals with the immediate aftermath of a disaster. In the Recovery stage, an impacted area is rebuilt, preferably to a state which is more resilient to the next impact event.

3.1.1 Integrating topic: flood risk management in urban areas

A major societal challenge in FRM is how to mitigate **flooding in urban areas**. Cities worldwide experience fast population growth and represent a large economic value but often have aging flood protection and drainage infrastructure, have limited space for protection and mitigation measures, and are complex areas to manage in crisis situations.

In 2025, we will focus on two cities, Zwolle in the Netherlands, and Beira in Mozambique to explore and contrast how to make these cities more resilient against flooding. Both cities are at risk of flooding due to wind set up, river flooding and direct rainfall, or a combination of these drivers (compound flooding). In both cities the space for adaptation measures is limited and collaboration between different levels of government is needed. In order to devise sound FRM strategies, we need optimal information from remote-sensing, modelling and data analysis, alongside locally appropriate flood risk reduction measures. Strong collaboration

between the city government, basin and coastal management authorities, and other institutions such as disaster risk management, environmental, agriculture or hydro-meteorological agencies at the national level can enable a wider range of flood risk management actions.

In this effort, we will apply in-situ and remote-sensed data to enhance information on the geophysical system (e.g., land elevation, bathymetry, land cover), flood-related infrastructure networks (e.g., drainage systems, regulated and unregulated flood defences, etc.) and hydro-meteorological forcing (e.g., localized rainfall prediction, estimation and nowcasting). We will use this information to optimize our compound flood hazard and impact models to provide actionable information on flood hazards and impacts, and use these models to explore potential prevention, mitigation and preparedness strategies. In this effort we will investigate hybrid modelling approaches that combine process-based models with empirical observations and AI models, and that can support both flood risk analyses in the prevention phase, as well as operational systems in the preparedness and response phase. We will also develop methodologies to enable multilevel governance interactions to understand and leverage collaboration across sectors. We will work with local partners, government agencies and international organizations to collect input information and discuss results in context of local questions and needs. A number of activities described in the below research lines contribute to this effort. The knowledge and tools developed in these two test cases can be applied to other cities in the Netherlands and abroad.

3.1.2 Effective and equitable flood risk management strategies.

This research line aims to contribute to strategies for effective and equitable flood risk management. Deltares provides knowledge, methods, and tools to develop these strategies consisting of consistent sets of measures that enable societies to cope with flood hazards now and in the future.

In 2025 it focuses on two main subjects:

1. *Vision on flood risk management strategies for the Netherlands*

This topic addresses mission 3A and 6A of the KIA (future climate proof and safe delta). In the last decade improved knowledge and understanding has been generated on behaviour of river- and coastal systems, on flood impacts and risks and on measures to reduce risks such as on different types of embankments. This new knowledge and its applications need to be translated into implications for the current strategy and potential visions on flood risk management. In the Netherlands, Deltares contributes to thinking of potential directions for flood risk management, by providing knowledge, by exploring alternative strategies and by relating different issues to find combined solutions for pluvial, fluvial and coastal flood risks. Potential concrete topics may include floods from the regional water system, flood risk management in the unprotected areas, deriving plausible flood maps for spatial planners and financial partners and flood risk management strategies for the future (including recovery and resilience). This effort will be executed in co-creation with the Ministry of Infrastructure (DGWB) and the Delta Programme.

2. *Operationalisation of criteria and guiding principles for FRM strategies*

To enable decision makers to consider synergies, trade-offs and co-benefits with other relevant criteria (such as resilience, efficiency, equity), information on the effect of FRM

strategies with regard to these criteria is required. This involves collaboration with different sector agencies such as water resources, disaster risk, agriculture, environment and hydro-met agencies. This research line addresses this by operationalising different criteria via indicators, developing tools to easily quantify the interactions and by show the impact of considering these criteria on the choice for certain strategies. It also proposes governance tools that assess multi-sector collaboration.

This topic contributes to SDG 10 and KIA Mission 6A linked with the aims of the Delta Program, and the Sendai Risk Framework).

For both subjects, knowledge and methods will be generated, tools will be developed, and cases will be carried out.

The research will consider river, coastal and pluvial floods. In the Netherlands it will focus on flood risk management for flood hazards from the main waterways, the regional waterways and from longer duration large-scale rainfall events. Internationally, the focus is on water systems and societies in flood-prone areas, thus on river deltas, areas drained by one water system or countries (and thus not on individual embankment sections, or individual buildings).

Co-creation and cooperation with external partners include PBL and the Delta Program, DGWB, Waterboards, Universities (TUD, UU), international institutes (e.g. GfZ Potsdam), and the World Bank. Internally, cooperation is foreseen with research in MS1 and 5.

3.1.3 Quantification of flood hazards, impacts and risks

This research line aims to provide the data and methodologies needed to quantify current and future flood hazards, impacts and risks at a system level. It supports the national mission for the Netherlands to develop sustainable measures that protect delta areas and increase resilience (LWV KIA Mission 6A), the BOI programme goals and contributes to global efforts to achieve the goals outlined in the Sendai Framework and SDG target 11.5, which aim to significantly reduce disaster-related deaths, affected populations, and direct economic losses.

In 2025 we will focus on two lines of activity:

- Quantification of compound flood hazards and impacts in urban areas: Linking to this Moonshot's *major challenge*, we aim to develop methodologies to utilize and blend locally available and remotely sensed data at scales relevant to the urban environment. Simultaneously, we aim to enhance our current compound flood hazard modelling methodologies to deal with the gap between available information on (informal) flood defences and drainage systems, and input requirements for high-resolution flood hazard modelling, including application of data-driven and ML methodologies. We will build upon earlier developments in Moonshot 2 to assess non-tangible societal impacts and the distribution of impacts and benefits among different societal groups. We will focus these developments on the Moonshot 2 case-study sites of Zwolle, the Netherlands, and Beira, Mozambique.
- Globally applicable, high-resolution risk assessment framework to rapidly assess compound and concurrent flood hazards: Supporting the objectives of the Sendai Framework and SDG 11.5, we aim to develop a risk assessment methodology consisting of data, hazard and impact models, and a probabilistic framework, to enable rapid

quantification of compound flood risk for any delta region in the world. Through developments in EO data acquisition, and improvements in reduced physics models, meta-models, and ML/data-driven models, we aim to provide risk information that has sufficient accuracy and resolution to support the development of sustainable flood risk reduction measures and strategies. In line with the Sendai Framework priorities on multi-hazard risk assessment, we will enhance our capability to rapidly quantify concurrent natural hazards, such as rainfall induced landslides, coastal erosion, and spread of pollutants and waterborne diseases.

In this program we aim for increased utilization of key research and development on compound flood risk modelling and assessment through knowledge sharing with, and transfer to, other parties. We anticipate potential outcomes of this research to link to the Kennis voor Keringen program in the Netherlands and to Horizon Europe research and innovation programs, such as Destination Earth. We aim for implementation of new insights, tools and models developed in this program to be implemented in risk assessment projects carried out by Deltares and market parties for local governments and international finance institutions.

In this effort we work together with Dutch national, regional and local government agencies, consultancies and academia, as well as international research partners such as the US Geological Survey, the US Navy and the UN World Food Program, and European partners through Horizon Europe research projects.

3.1.4 Effective and sustainable reinforcement and management of primary flood defences in the Dutch Delta

In the Netherlands, the Flood Defence Act of 2017 requires that all primary flood defences (levees, dunes and structures) must comply with the legal safety standards in 2050. The first safety assessment (LBO1) indicated that 2,000 km of the 3,500 km of the Dutch primary flood defences require a reinforcement indicating a total cost of 24 billion Euro until 2050 (MinI&W) and significant societal impact.

The Dutch government agency DGWB is responsible for providing a framework to perform this safety assessment (BOI - assessment and design framework). The Dutch Flood Protection Programme (HWBP - Hoogwaterbeschermingsprogramma) is responsible to design and carry out strengthening projects to achieve the legal safety standards. New legislation on nitrogen emissions, nature conservation and a shortage on physical space and materials, capacity (of people) and funds make this task even more challenging. Water Authorities such as Water Boards and Rijkswaterstaat are responsible for the asset management of primary flood defences (“Zorgplicht”) which includes inspections and maintenance.

Increased and implemented knowledge related to the strength and loads on primary flood defences contributes to:

- Acceleration and optimization of the HWBP task so that in 2050 all primary flood defences comply to the legal safety standard, leading to lower costs, lower hindrance and higher social acceptance.

- Improvement of inspections, maintenance and calamity plans lead to optimized asset management (Zorgplicht, Kustlijnzorg).
- Both asset management and reinforcement have to be performed with potential decrease in use of energy, raw materials (incl. circularity) and a-biotic materials as well as improved use of nature-based-, nature inclusive-, and sustainable solutions contributing to the innovation programs 6A and 6B of Mission 6 of MMIP-AWF.

To optimize the anticipated impact, it is essential to cooperate with relevant partners in the sector (RWS-WVL, HWBP, Waterboards, DGWB, innovators, universities, consultancies) including international cooperation to peer review the research and to use international available knowledge.

Deltares role is to oversee all relevant technical aspects of determining the failure probability of primary flood defences which requires thorough understanding of probabilistics, geotechnical strength, hydraulic loadings and structural response. Within this SITO-IS research line we focus on identifying, initiating and elaborating new insight and developments. Activities in this research program have an incubator and/or interconnection function and can, when feasibility is shown, be further developed and eleborated, within other knowledge projects such as Kennis voor Keringen, BOI, or HWBP-KIA projects. The foreseen impact is on:

- the HWBP scope, in the form of a smaller required reinforcement scope, lower costs and faster implementation within given societal demands such as minimising societal hindrance, less energy and sparce material use, more environmental friendly, circularity, biodiversity, use of natural solutions to mitigate flood risk (Nature-based Flood Solutions) and inclusive solutions for nature and biodiversity.
- Maintenance (Zorgplicht and kustlijnzorg): improving assessment, inspection and maintaining by developing prototypes or feasibility studies for relevant topics such as use of drones, aspects related to cracks in levees, animal burrowing, and maintenance of sandy coastlines.

3.1.5 Preparedness and Recovery: disaster warnings and crisis management

In this research line we aim to provide global coverage and locally relevant compound flood forecasts, disaster warnings and crisis management information. Global coverage enables us to address flooding issues worldwide, while local relevance allows us to make impact on specific areas. We will contribute to the major challenge of urban flood forecasting'.

We aim to achieve the following Impact:

- The Netherlands is well prepared for high water and flooding, including during crisis situations, through timely and accurate warnings. We aim to develop and provide tools that support achieving this goal.
- Provide a steppingstone to UN Early Warning for All initiative (EW4All).

Global flood forecasts can offer valuable information to data-scarce regions where detailed local models are unavailable, which supports the UN's EW4All initiative. These forecasts need to cover the globe with relatively high resolution, be fast enough to provide sufficient

lead time, and be capable of supplying boundary conditions to local models. Additionally, we will provide locally relevant forecasts through a downscaling and correction approach, ensuring higher resolution and integration of any available local data. Forecasts must be robust and reliable, preferably linked to flood impact and including uncertainty information. We also need to understand how uncertainty information can aid decision-making during extreme events. Actionable information is crucial during emergency responses.

Artificial Intelligence (AI), in particular, can assist in providing fast surrogate models and ensemble forecasts with uncertainty information. While our process-based flood models have become more efficient, they remain quite expensive. In 2025 we will propose 'AI to improve flood forecasting' as a new topic and will focus on developing fast-running AI models. AI models require a training dataset which can be provided by well-calibrated process-based models. These flood reanalysis datasets are invaluable for training and benchmarking AI models as they offer a consistent and accurate record of past extreme events. Continuously improving traditional flood models and generating flood reanalysis datasets is another key focus. Hybrid approaches combine traditional process-based models with AI techniques to leverage the strengths of both. While process-based modelling approach is highly valuable, AI can optimize model parameters, perform bias correction and assimilate real-time data to enhance forecasting skills. Those aspects of hybrid modelling will be another focus. These AI-related topics present a new research frontier and have not been explored before in this Research Line.

Our partnerships with Dutch and international governmental agencies help set up national (RWsOS) and regional flood early warning systems (60+ countries worldwide). We also work with global financial institutions like the World Bank and the Asian Development Bank to assist developing countries in establishing flood early warning systems. Additionally, we engage with Dutch and international consultancy companies in delivery operational flood forecasting services, insurance companies in areas such as parametric flood insurance.

3.2 Knowledge facilities

This Moonshot draws on the products developed in the **Enabling Technologies** program, such as worldwide topographic data sets as input for flood models, remote-sensing techniques to detect flood extents and land use changes, and AI techniques to improve flood modelling and forecasting. These products typically have a low TRL level (1-3) and are applied and validated in research applications within SITO-IS before they can be used in market projects and/or shared with the larger community.

Despite recent advances in AI techniques, the quantification of flood hazards and impacts typically requires numerical simulations. For this purpose, a wide range of **software** is used of which different products are incorporated in global, regional and local flood modelling systems. Within SITO-IS, many of these products are validated and conceptual new developments are proposed and conducted. Flood risk assessments and forecasts require extensive input data and generate larger volumes of output data. We work with the Knowledge Facility on **data** regarding how to best retrieve, use, store and compress data. Furthermore, numerical simulations need to be performed at increasingly larger scales and

significantly higher speeds. To this end we are involved in the **Digital Transformation** to explore GPU implementations of flooding software.

Experimental Facilities are the key to explore the complex processes of geotechnical deformation, and wave, flow and sediment interactions on coasts in isolation. Experimental data sets are also invaluable to validate and improve numerical models. Examples of these are experiments in the Delta Flume on clay covers on dikes, reduction of waves due to mangroves and coral reef elements.

The interaction of this Moonshot with the Knowledge facilities is described in further detail in chapter 7. More detail about the connection between the Product lines and the Moonshot can be found in chapter 7.3 and Appendix A.

Deltares

4

Resilient and healthy water and subsurface systems for humans and nature

enabling delta life

4 Resilient and healthy water and subsurface systems for humans and nature

Figure 4.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the moonshot: Resilient and healthy water and subsurface systems for humans and nature.

Healthy, well-functioning ecosystems, including water and subsurface, form the basis of our existence and are the first physical line of defence against climate change, overexploitation and pollution. However, water and subsurface are under pressure worldwide. Leading to societal challenges such as long-term drought and water scarcity, depletion of resources, soil subsidence, excess nutrients and contamination of surface and groundwater and a decline in biodiversity. This has major consequences for people, nature and the economy: World-wide 2 billion people have no access to clean drinking water. This century, about 1.5 billion people around the globe have been directly affected by drought. Pollution of the environment was responsible for 9.0 million premature deaths in 2019. Over 50 years, there has been an average 69% decline in wildlife populations around the world. In the Netherlands we face challenges in complying with the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD), we are confronted with a nitrogen crisis and during recent dry summers faced significant challenges in water distribution. It is complex to provide ecosystem services for a changing world, whilst respecting planetary boundaries. Stakeholders in the Netherlands and across the globe aim to halt and reverse the negative trends and improve the living quality and consequently, human health. This requires transitions in the field of agriculture and food, circularity, energy, water and spatial planning.

This moonshot addresses the transition towards more resilient and healthy water- and subsurface systems. Enabled by scientifically sound perspectives, solutions and strategies based on understanding of changing water and subsurface systems, stakeholders can adopt the necessary integrative approach to water and subsurface management for landscapes

undergoing transition (outcome). We align our outputs and activities along six impact storylines focusing on water availability, (ground)water quality, and biodiversity and along the integrative approach towards transitions in river basins, coastal areas and seas, and the built environment (Figure 4.2).

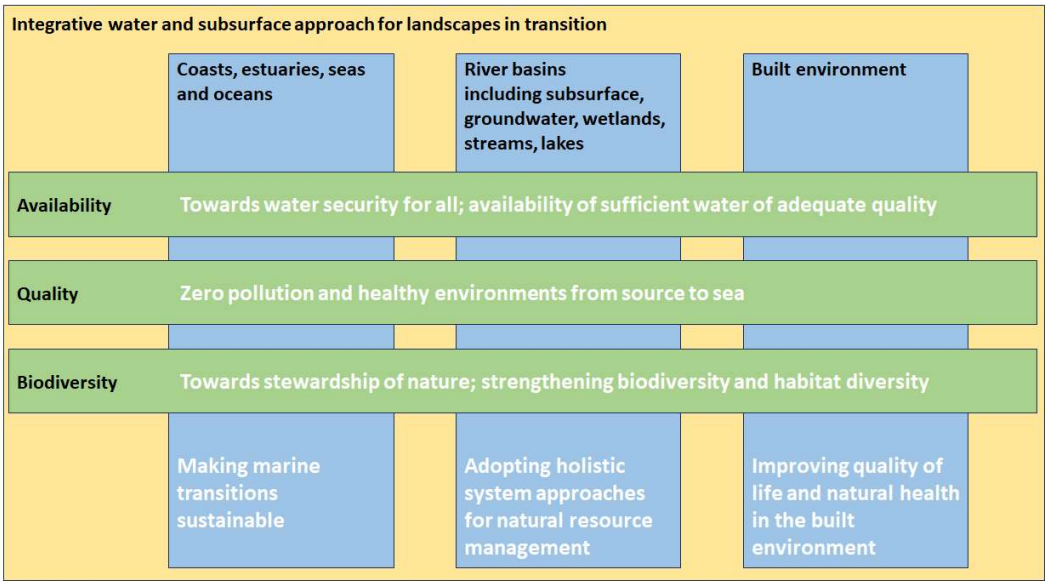


Figure 4.2 - Overview of impact storylines (in white) and topics and landscapes (in black).

Our integrated knowledge and software of groundwater, surface water, and subsurface systems forms the basis of our activities and output. This encompasses hydrology, hydro- and sediment dynamics, morphology, and ecology, as well as socio-economic, governance, and institutional insights. We assess and unravel current and emerging risks and uncertainties, developing, testing, and evaluating approaches, nature based and hybrid solutions and strategies, partly through conducting experiments and measurements in our facilities and in the field. By doing so, we provide decision-makers with accurate information to make better-informed decisions, even in emergency situations where resources are suddenly lacking.

We focus on the present day, the coming seasons and decades, from acting upon present day issues and critical events to making the best decisions for the long term. The goal is to enable stakeholders to understand the water and subsurface systems under change and to jointly make them healthier and more resilient.

4.1 Research activities

The activities in the impact storylines contribute to research in the Netherlands and around the world, in collaboration with knowledge partners, stakeholders, and clients such as ministries, cities, and other authorities, the European Commission, and the International Financing Institutions. There are commitments to projects with consortia and investments in so-called bold ideas within Deltares to create more focus and impact.

4.1.1 Towards zero pollution and healthy environments from source to sea

We enable national, European and international stakeholders to better manage pollution by nutrients, (micro)plastics, pathogens and chemicals, including persistent toxic substances, in order to better comply with (inter)national guidelines and regulations, such as WFD, MSFD and OSPAR. We advise on environmental policy, water and land management from local to national level and we also work in support of the health sector. We use systems approaches to assess impacts and interventions, such as the source-to-sea approach for pollutants and the pathway approach for public health. Our multidisciplinary research teams work in an integrated way on pollutants at different scales in groundwater, streams, rivers and seas, in the laboratory, with model simulations and in the field. We jointly develop and assess policies to control pollution and we provide tools for assessing, monitoring and modelling emissions and the quality of water, subsurface, sediments, and ecology. We design, test, and evaluate (nature-based) solutions to remediate and clean-up the environment. Through this, we work towards healthy environments for humans and nature.

Table 4.1 - Foreseen activities in Sito IS in 2025

Towards zero pollution and healthy environments from source to sea			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Pollution pathways from source to sea: common and unique elements for different types of pollution and identification of missing links, roadmaps to mitigate exposure Illustration of needs for pollution reduction for stakeholders Possible and feasible water quality goals as well as supporting measures	Sito PS Verontreinigingen (Water- en Bodemkwaliteit) TKI Van bron tot effect TKI Afbouw Nazorg	Deltalab Monitoring trailer Deltares Software	Microplastics sediment Waal EU PROMISCES EU NINFA EU NAPSEA EU BlueAdapt EU TULIP MOMENTUM 2.0 WINC Environmental Technologies HUB GLORIA DESTRESS EU GREENHOOD

**selection; other than Sito IS; focus on Sito PS and TKI*

4.1.2 Towards water security for all; availability of sufficient water of adequate quality

We enable stakeholders to work on increasing water security, the availability of sufficient water of adequate quality, nationally, internationally and transboundary. Our knowledge enables governments, regional authorities, community leaders and international development organisations, both in the Netherlands and abroad, to make informed decisions about the allocation of water between various functions and needs, and to effectively manage drought risks and (ground)water quantity and quality. We work in an integrated way on the knowledge of different compartments of water and subsurface for various sectors that require resources, such as drinking water, nature, agriculture, shipping, cooling, warming, groundwater management, hydropower, by applying system understanding and using local knowledge. We provide instruments to generate vulnerability analyses and risk assessments: (quick scan) tools, forecasting, operational information systems (e.g. drought monitor), modelling frameworks and early warning systems. In addition, we work on design, quantification and scaling up of (nature-based) solutions in water and subsurface systems in different landscapes.

Table 4.2 - Foreseen activities in Sito IS in 2025.

Towards water security for all; availability of sufficient water of adequate quality			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Quantify system response (water quantity, quality, biodiversity) under different events, measures, scenarios (magnitudes flooding, drought, adaptive measures) for science-based decision making to support governments in the implementation of conjunctive water management to increase water security: Improving Drought preparedness; Develop Large scale managed aquifer solutions; Quantify and scale-up nature-based solutions.	Sito PS Waterbeschikbaarheid Sito PS Water, Bodem, Ruimte	Deltares Software	STW SALTI WMO global status and outlook of water resources NWO Aquaconnect NWO Wunder NWO NAT PvW ASR Domestic Freshwater Supply to the Mekong Delta NWO KIC STURDI-Water EU NBRACER Dynamics of NbS (Korea/Aalto/Polen) EU Spongescapes EU Danube4all

**selection; other than Sito IS; focus on Sito PS and TKI*

4.1.3 Adopting holistic system approaches for natural resource management

We work on strategies for the health and resilience of water and subsurface, to use and manage resources sustainably, taking into account people, planet and prosperity. Our knowledge enables stakeholders to tackle wicked problems and to work on responsible, sustainable and equitable (regional) spatial planning, while minimizing negative effects and creating positive effects on ecosystems and their services. In this, we take a holistic approach to transitions in the field of agriculture and food, circularity, energy, water and spatial planning. In the holistic approach we are using methodologies to work on complex multifaceted issues, such as Integrated Water Resources Management, Source-to-sea, Systems Thinking. This enables governments to simultaneously address floods, droughts, water quality and biodiversity. We work on (policy) frameworks, integrating monitoring tools and modelling insights on hydrology, water quality and morphology, and providing solutions and action perspectives for landscapes in transition and possible pathways to the future. We contribute to fit-for-purpose decision-making processes, implementation processes and impact assessments, and develop knowledge and strategies for (inter)national organisations and partnerships. Coordinated measures with neighbouring countries can significantly enhance the effectiveness of solutions. Exploring opportunities to innovate and learn from each other is vital. Joint knowledge development with institutions in neighbouring countries supports the justification, acceptance, and commitment to addressing issues and implementing solutions.

Table 4.3 - Foreseen activities in Sito IS in 2025.

Adopting holistic system approaches for natural resource management			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Which approach is applicable to which wicked problem, where/when to use, how to apply, how to develop, and how to combine different holistic approaches, expanding the role of co-creation, data science and knowledge for informed decision making and scaling up governance and expert collaboration for effective governance, common understanding and joint timely messages and communication: Holistic approaches to water and subsurface; Transboundary water management; Water-related migration and social stability; Integrated area approach for rural NL.	LN2025 Sito PS Water, Bodem, Ruimte	Deltares Software Enabling technologies (LLM/AI)	Supervision PhDs on Refugee settlements Water-Energy-Food and Health in South Africa IWRM and Refugees Cultural Heritage in Motion EU STARS4WATER

**selection; other than Sito IS; focus on Sito PS and TKI*

Nature-Based Solutions across all five of our moonshots

Forefronting transformative Nature-Based Solutions for sustainable impact

We position and prioritize nature-based solutions (NBS) as a cross-cutting theme in our activity plan, NBS are integral to all five of our moonshots and play a key role in the global shift toward sustainable delta management. Deltares is committed to advancing NBS knowledge, making them comparable to other intervention options and supporting their mainstream adoption alongside our partners.

Since NBS first gained attention around 2008, the landscape has evolved significantly. While early on there was limited understanding of NBS potential, today there is abundant evidence and numerous examples across different ecosystems demonstrating the tangible benefits of NBS and the conditions needed to achieve them. Global and local stakeholders are now more aware and eager to advocate for and implement NBS.
The central challenge is how to effectively integrate and mainstream NBS into landscape and delta management practices. We see two broad approaches emerging: the ‘quick-fix’ NBS pathway and the slower, more ‘transformative’ approach.

The quick-fix approach mirrors past efforts to optimize technological systems, treating NBS as a readily deployable solution. Deltares can play an important role in making NBS quantifiable and comparable to engineering solutions. For example, by measuring NBS effectiveness in its physical facilities and by showcasing NBS potential and uncertainties through numerical modelling. This furthers implementation of NBS in combination with grey infrastructure and aids development of NBS guidelines. Next to this, the transformative approach views NBS as a tailored approach that emerges from an inclusive process, considering physical, ecological, and social systems. This method begins with a comprehensive survey of the system, mapping out how NBS can address specific challenges. Deltares needs to operate in a more complex playing field here, bridging between disciplines and backgrounds. However, Deltares can tap on a long history of water resource and coastal zone management and on its international network to facilitate transformative NBS. Also, linking with planning under uncertainties and pathway approaches to develop useful concepts and frameworks to unlock the full potential of nature-based solutions.

These observations form the foundation for rethinking and crafting an actionable NBS strategy, positioning Deltares to contribute meaningfully to the global advancement of NBS.

4.1.4 Improving quality of life and environmental health in the built environment

We enable stakeholders to work on improving the quality of life and environmental health in the built environment and enhance urban resilience. We enable municipalities and regional governments to make robust plans and take decisions on spatial planning and efficient use of resources. By providing knowledge (status, dynamics, vulnerabilities, and risks), tools (digital twins, assessment, planning, design, monitoring), interventions (nature-based, hybrid) and climate-robust solutions, our partners are better able to anticipate climate change, protect biodiversity and increase the quality of life, with water and soil as guiding principles. Here we deal with soil health, water quantity and water quality effects, for example of droughts, disconnecting rainwater from the sewer system, and constructed wetlands/wadis. With insight into the trade-offs and synergies around water distribution, water availability, soil vitality, remediation, groundwater dynamics and hydrological conditions and system functioning of the urban area, we contribute to healthy urban soils and safe use of water by urban communities, improving quality of life and environmental health in the built environment.

Table 4.4 - Foreseen activities in Sito IS in 2025.

Improving quality of life and environmental health in the built environment			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Define soil health in an urban living lab setting and quantify, design and test nature-based and hybrid solutions for water and soil, to optimize co-benefits for urban quality of life, for climate robust and healthy spatial planning	Sito PS Water, Bodem, Ruimte	Deltalab Deltares software	EU SOILL EU PREPSOIL EU ISLANDR EU SPADES EU PHISHES EU COMMIT2GREEN

**selection; other than Sito IS; focus on Sito PS and TKI*

4.1.5 Towards stewardship of nature; strengthening biodiversity and habitat diversity

We work on creating awareness of the urgent necessity to improve the resilience and health of the water and subsurface systems, as this is the basis of nature and human life. With this we enable and inspire stakeholders to act on this awareness and to make sustainable use of resources and services. We do this by giving water, subsurface and ecosystems a voice through digital and innovative technology, we produce digital twins and we analyse the signals that natural systems produce; digital representation of nature to stimulate better management of nature. We inform stakeholders in an inspiring way about drivers, status and trends in the water and subsurface system. In this way we offer citizens, authorities and decision makers the insights to take action to preserve and restore habitats in water and subsurface, and thus biodiversity in general.

Table 4.5 - Foreseen activities in Sito IS in 2025.

Towards stewardship of nature; strengthening biodiversity and habitat diversity			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Make guidance for stakeholders for stewardship of nature (dashboard), containing digital tools and innovative techniques to: using digital and innovative technology to realize dialogues with nature , and understand, diagnose and predict biodiversity and abiotic boundaries for habitats of key species in soil and water.	TKI Power-of-nature-based-design (POND) Biodiversity planner Landschapstype dashboards Sito PS KRW Verkenner PAGW, DPZW	Deltalab Deltares software Enabling technologies (LLM/AI)	EU OBAMA NEXT EU MERLIN EU FUTURE LAKES PhD RUN Biodiversity and Human Health

**selection; other than Sito IS; focus on Sito PS and TKI*

4.1.6 Making marine transitions sustainable

We work on the scientific basis for sustainable transitions in marine and coastal waters. These waters are more and more intensively used, not only in the Netherlands, but also worldwide. They provide services such as transport, energy production, sand extraction, recreation, logistics and food production and thereby are key for the economy and human health and well-being. They are also ecologically important and host a wide range of organisms and valuable habitats. Many initiatives, including European policy directives, aim to protect and restore ecological health in seas, both by reducing pressures and creation of marine protected areas. However, the economic activities at sea, land-based pollution and climate change may pose a threat to their desired healthy status. Economic activities and protected areas may also negatively impact each other or compete for space, which requires careful marine spatial planning. Science-based policy implementation and mitigating measures require a sound understanding of how the complex interplay of pressures and potential measures will affect marine ecosystems. It is often a challenge to understand and predict how changes in physical and chemical variables will impact ecological indicators. This requires smart data science methods supported by large amounts of observation data and strategic collaboration with research partners and stakeholders. Thus, we enable stakeholders to effectively plan measures to protect ecological health of marine and coastal ecosystems and the services they provide. (Note: This storyline is strongly connected to other moonshots, especially the one described in the next chapter).

Table 4.6 - Foreseen activities in Sito IS in 2025.

Making marine transitions sustainable			
Priorities Sito IS 2025 (to address in bold ideas)	*Collaborating projects**	*Deployed Deltares facilities*	*Connected commitments in Sito IS of this moonshot*
Develop and present perspectives of possible futures of the marine environment with respect to a healthy and resilient water and subsurface, with special focus on the Wadden Sea.	Sito PS BO Wadden; MONS; Wozep; PAGW streefbeelden	Deltares software Enabling technologies (LLM/AI)	NWO Sedways NWO Saltgarden EU BLUE CONNECT EU FOCCUS EU DOORS EU ULTFARMS NWA Floating Future EU PHAROS EU TRIDENT

**selection; other than Sito IS; focus on Sito PS and TKI*

4.2 Knowledge facilities

This Moonshot is intertwined with our **digital transformation**. We develop software that is integrated, automated, multi-scale, consistent, flexible, and able to do scenario-analyses and forecasting, based on a stakeholder-centric vision and roadmap in an agile manner. The vision and roadmaps for the software provide scientific toolboxes, impact models and knowledge-based tools for interaction with stakeholders. As advancements accelerate in artificial intelligence and data collection, the field offers increasingly sophisticated opportunities for data-driven modelling. Causal machine learning, enables robust assessment of ecosystem services amidst climate change by uncovering causal relationships between environmental variables, facilitating what-if predictions and informed decision-making for adaptation and conservation strategies. The Product lines of Deltares develop and maintain software that can be applied for the storylines of the moonshot narrative. The most important software developments for this Moonshot are in the field of water quality, ecology, hydrology, hydromorphology and water operations.

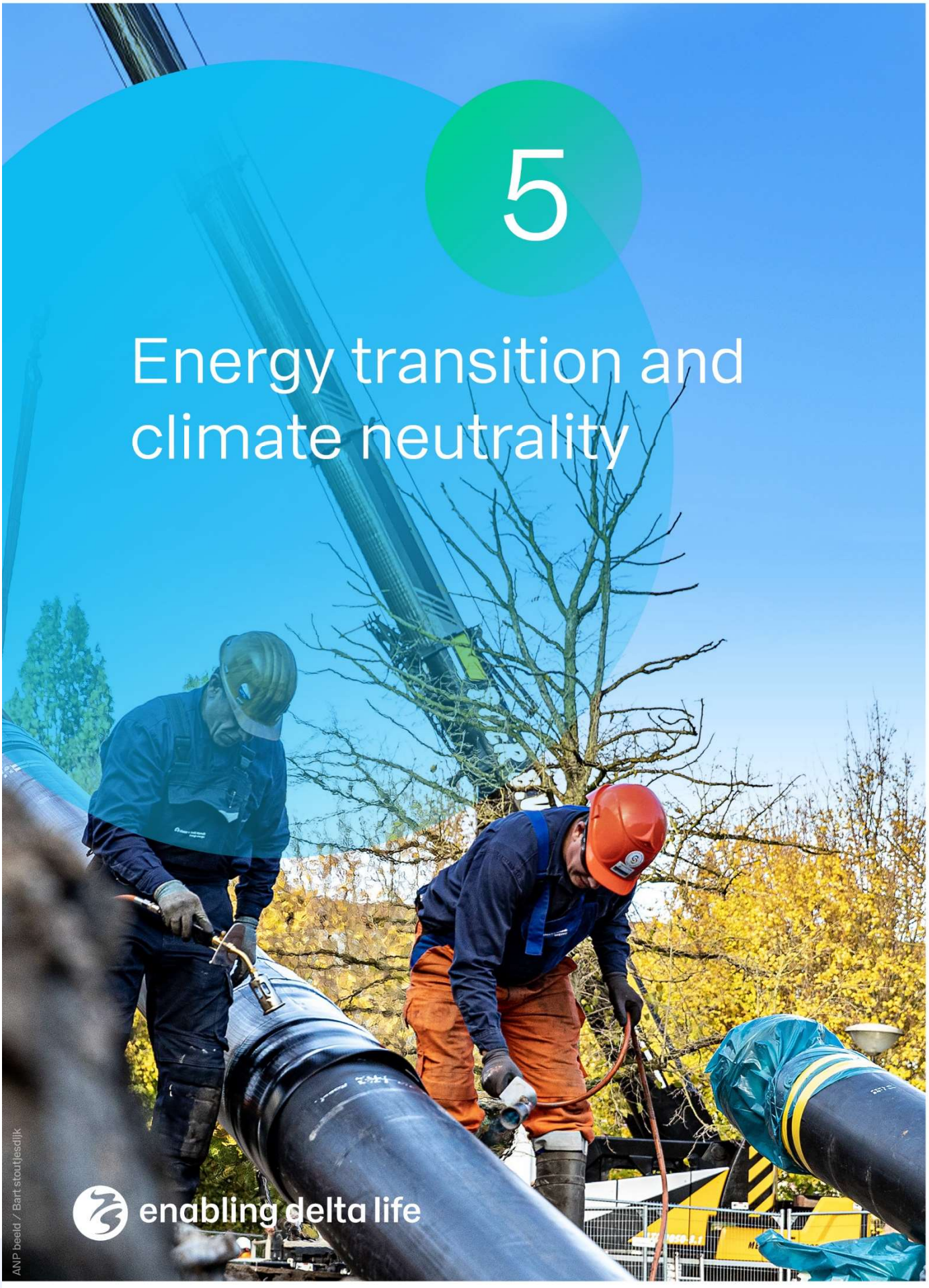
The **experimental laboratories and facilities for fieldwork of Deltares**, including the Deltalab with its laboratories for microbiological, geochemical and physical experiments, Geohal and Hydrohal and a monitoring trailer for water quality analyses in the field, offer unique research opportunities on a lab, pilot, and field scale for this Moonshot in particular: In the **Deltalab**, we conduct experimental research on ecological and chemical quality of water and subsurface systems. We experiment with innovative techniques to measure and analyze the substances, microorganisms, and greenhouse gases (see also the next chapter) in the soil, sediment and water system and their properties, transport and emissions. The Deltalab works on ways to influence and manage these substances and microorganisms, and to find solutions to deal with harmful substances. Experimental results are being used in combination with and as input for models. Micro scale experiments are scaled up to pilot scale experiments. In this way, the Deltalab is the crucial element in understanding the quality of water and subsurface systems.

The interaction of this Moonshot with the Knowledge facilities is described in further detail in chapter 7. More detail about the connection between the Product lines and the Moonshot can be found in chapter 7.3 and Appendix A.

Deltares

5

Energy transition and climate neutrality



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5 Energy Transition & Climate Neutrality

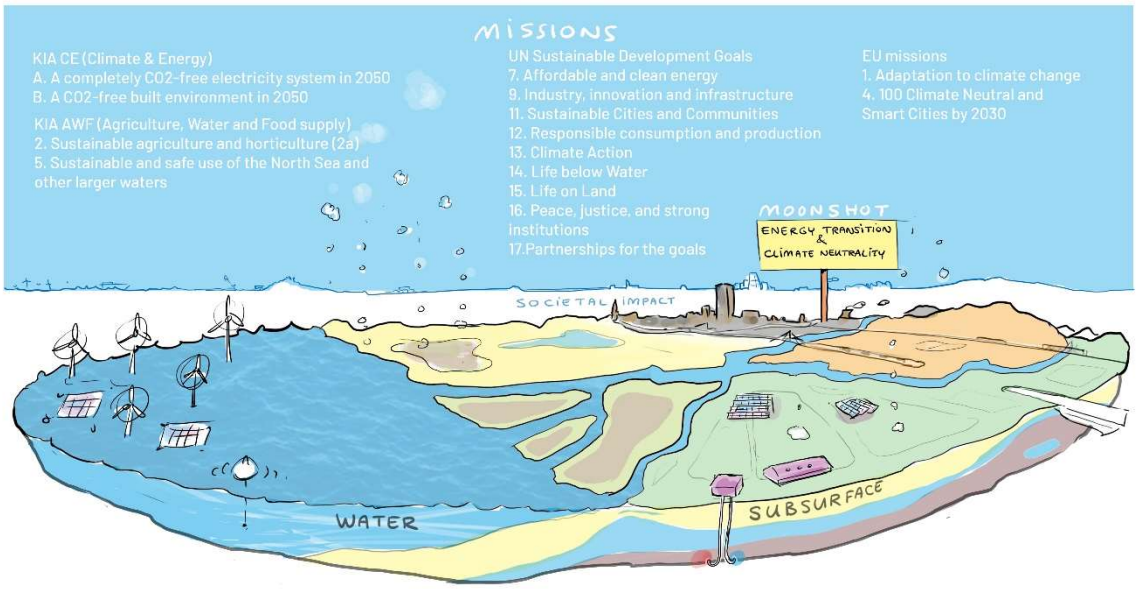

Figure 5.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the moonshot: Energy transition & Climate Neutrality.

The urgency to combat climate change due to greenhouse gas emissions is increasing. Almost 200 countries have committed to the Paris Agreement to limit global warming to a maximum of 2.0 °C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Within the EU, there is agreement to be climate-neutral by 2050 at the latest to implement this. The EU member states have also agreed upon a CO_2 reduction of at least 55% less by 2030. To ensure that this goal is achieved, the Dutch government is aiming at reducing greenhouse gas emissions by 60% in 2030. This is considered as one of the biggest societal challenges of our time.

Our Moonshot impact statement is as follows:

To achieve climate neutrality and accelerate the energy transition by 2050 through the responsible use of water, subsurface, ecosystem, and required infrastructure, and in synergy with climate adaptation, strengthening biodiversity and other goals, while working within the value chains.

Deltares is aiming for the following generic outcome for this moonshot in the coming years:

Unlocking water and subsurface opportunities for climate mitigation by 2030, developing:

- Strategies and adaptive pathways to support policy making and integrated planning processes.
- Well designed and constructed energy systems that contribute to the energy mix.
- Integrated systems analysis approaches to assess ecological and spatial effects and identify net positive (carbon) opportunities.

Guidelines, assessments and tools for:

- Planning, design, implementation, operation and maintenance of energy infrastructural networks and objects in water-, subsurface- and ecosystems.

A shared knowledge base with stakeholders in the value chain:

- Build up with national and international consortia.
- With the use of the Deltares knowledge base, digital and physical facilities, and validated in lab and field experiments.

We organize our applied research in three portfolios wherein we specify the general outcomes mentioned above per research portfolio:

1. Sustainable heating and cooling in resilient cities aims for:

- National target 2030: 500.000 extra houses connected to sustainable collective heating systems.
- Increased synergy between policies by ministries of EZK, BZK and I&W.
- Municipalities use integrated decarbonization pathways, co-developed by Deltares.
- Stakeholders use guidelines and our courses for design and operation of sustainable district heating/cooling.

2. Sustainable electricity generation and transport in large waterbodies aims for:

- National target 2030: 21 GW Offshore Wind.
- National target for floating solar in 2030: 3 GW (mainly offshore).
- Furthermore, an estimated global installed capacity of floating solar of 10-30 GW by 2030 is foreseen. (DNV, the future of floating solar).
- Enable responsible policy-making for sustainable electricity infrastructure on water, using engineering-ecology-policy interactions.
- Enable cost- and risk-reduction for upscaling of infrastructure within the ecosystem and spatial boundaries.
- Contribute to net-positive (net-gain) ecological impact at system scale.

3. GHG emissions and storage in land and water management aims for:

- EU target: 95% GHG emission reduction in 2050; at least 55% reduction in 2030 (EU and Dutch Climate law).
- EU Target sector LULUCF (land use/land use change and forestry) are 15% net negative (carbon uptake outweighs greenhouse gas emissions) in 2030.
- Deltares has tools (models, lab and field facilities) available to predict emissions and carbon uptake under different conditions and to evaluate different policy options and measures.
- Deltares directly contributes to greenhouse gas emissions registrations from (peat) wetlands (organic soils), salt marshes and water bodies.

5.1 Research Activities

5.1.1 Sustainable heating and cooling in resilient cities

One of the goals of the Dutch Climate Agreement is to decarbonize 1.5 million homes in 2030. The water and subsurface systems can play a major role in these decarbonization efforts with sustainable collective heating and cooling systems. That's why Deltares works on system integration, focusing on the smart design, construction and control methods, and on strategic planning of these systems as well.
Within portfolio 1, our activities primarily focus on the Netherlands. The reason for this is that the field of heat supply is highly complex, involving many stakeholders. To make an impact with our knowledge, it is essential to thoroughly understand the governance setting. Only in this way can we effectively fulfill our role in this value chain.

Our current portfolio exists of a combination of specialist consultancy, courses, software support and collaborative R&D projects. These R&D projects are funded by subsidies such as the National Grow Fund subsidy (NieuweWarmteNu!), TKI-projects and MOOI-programs and co-funded by SITO IS. We have recently submitted three new MOOI proposals. Deltares is actively engaged with TUDelft to concentrate academic R&D in the Netherlands on this portfolio. Because of the urgent societal needs, we are committed to increase our SITO-Program Subsidy portfolio from the relevant Ministries (I&W, BZK, EZ, KGG). Sustainable heating and cooling transition is a wicked problem. Many aspects need to be addressed at the same time to make the transition a success. So, cooperation with all relevant actors and a strong knowledge ecosystem is conditional. Joint efforts are required from various government levels, businesses, consultancies, housing corporations and citizens. With this we want to strengthen the heat value chain of sustainable collective heating and cooling systems.

Deltares will supply knowledge and expertise to design and manage sustainable collective heating systems. 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, in cost-efficient construction and optimal integration via demand response strategies and power-2-heat system integration.

In addition to work on geothermal energy and making heat networks more efficient, the focus in 2025 will primarily be on developing mitigation pathways to enable municipalities to create and explore various scenarios.

Table 5.1 - Selection of foreseen activities in line 1 in relation to the experimental and digital facilities.

	Programs and projects	Connection with facilities (both digital and experimental)
1.	NWN – Design toolkit District Heating Design Toolkit Warmtenetten - Nieuwe Warmte Nu (nwn.nu)	WANDA
2.	MOOI WarmingUP GOO on HT-ATES	Operational integration (via FEWS) of HT-ATES in district heating systems
3.	NWN – Affordable, reliable wells for HT-ATES. Betaalbare en Betrouwbare Bronnen voor HTO (3B HTO) - Nieuwe Warmte Nu (nwn.nu)	Includes experimental research (Geo-Lab) to optimize allowable subsurface design flow velocities.
4.	Ecological impact of filters used in harvesting heat from surface waters (KEEN).	Deltalab and D3D
5.	MOOI MaxFlex-ZLT (foreseen) on operational use of ATES and building thermal inertia to mitigate power grid congestion and deliver other energy system services.	WANDA Heat and Control will be used intensively to validate advanced controls and optimization of 5GHDC-systems.
6.	MOOI CHILL (foreseen) contribution to substantiate cost and benefits of insulation of ultra-low temperature grids.	KRATOS
7.	MOOI Diameter (shallow geothermal energy) (foreseen)(	
8.	Developing mitigation and transition pathways for municipalities and provinces	Approaches in Planning Toolkit to identify tipping points in the concurrent development of individual and collective heating/cooling solutions.

5.1.2 Sustainable electricity generation and transport at large water bodies

The emphasis of this portfolio is on renewable energy infrastructure on water, with a focus on offshore wind farms and floating solar on both inland and offshore waters. Large-scale offshore windfarms or floating solar farms play a critical role in decarbonizing the power system in a sustainable way. Achieving the national and international targets for offshore wind and floating solar lead to a number of challenges in the field of engineering, ecology, and marine spatial planning. The ambition in this portfolio is to enable achieving these targets for development of offshore wind and floating solar with specific attention for the responsible use of water, subsurface and ecosystem during the development of the required large-scale infrastructure.

For floating solar on inland water Deltares has initiated a significant amount of work on ecological impact not only for private companies and national authorities but also within European partnerships (Horizon). For offshore floating solar the research is both on ecological impact and on engineering aspects of offshore floating solar. The main ambition for the coming years is to achieve a strong portfolio where all Deltares disciplines are incorporated. To make more impact further integration with knowledge outside Deltares is necessary and therefore another ambition for the portfolio. The portfolio will pay special attention to spatial planning aspects associated with the integration of both offshore wind and offshore floating solar.

To achieve our goals, we strengthen our collaborations with the private sector throughout the supply chain (such as wind and solar farm developers, offshore contractors, equipment suppliers), certifying bodies, knowledge institutes, and government bodies. The input from the private sector is essential, while the involvement of certification bodies ensures the

knowledge and models developed as an output of the research can be used at scale in practice. Through commitment and active collaboration from all parties we increase both broad support and uptake of our (joint) research output.

Deltares' role in the offshore wind sector has mainly been on the engineering side where we contributed to reduction of cost and mitigation of risk through applied research in collaboration with the private sector (for example, JIP HaSPro and JIP SIMOX). Recently, ecosystem effects and marine spatial planning have been put on the agenda through flagship projects like WOZEP.

Deltares' role in development of renewable energy on water is to provide output that enables science-based decisions and innovations that are needed for the upscaling of offshore energy, ensuring:

- Well designed and constructed energy systems.
- Guidelines for the sustainable use of floating solar and offshore wind. We develop a database of monitoring data which can be used by both permitting bodies and energy companies, as well as monitoring strategies and modelling tools.
- (Marine) spatial planning support tools.

The activities that we perform in 2025 will focus on integration of engineering research with ecology and (marine) spatial planning aspects. We will make use of our unique experimental facilities and of our digital tools, varying from detailed numerical models to engineering toolboxes.

Table 5.2 - Selection of foreseen activities in portfolio 2 in relation to the experimental and digital facilities.

	Programs and projects	Connection with facilities (both digital and experimental)
1	Optimizing Pile Installation through Scour Protection grow-offshorewind.nl/project/opis	Water-soil flume, Delta flume
2	Hybrid labs – Integrated Digital & Physical Models and Offshore Demonstrators for Floating Wind Farms Hybrid Labs (tudelft.nl)	Geocentrifuge
3	Reducing Uncertainty in Wave predictions	Delta flume, Atlantic Basin, Scheldt flume, CFD (OF)
4	Nature Inclusive Design for Oceans	Atlantic Basin, Delft3D, DST
5	Ecoamare ECosystem-based Adaptive MAnagement for REnewable energy in a sustainable North Sea (ECOAMARE) | NWO	DST
6	Monopile Improved Design through Advanced cyclic Soil Modelling in Clay (MIDASclay)	Geocentrifuge, possibly Water-Soil flume
7	Light modelling; balancing performance and ecology (KEEN) in cooperation with TNO	Delft3Delwaq
8	Ecological impact modelling of floating solar and wind farms	Delft3D

Our input consists of our own cumulative knowledge base containing results of previous (external) research and commercial projects, as well as field data. Furthermore, use is made of open-source software and in-house developed models and toolboxes. An important boundary condition for the work performed in this Moonshot is the availability of our experimental facilities.

We will use data from a database of previous (external) research projects and, where possible, real offshore data, to validate and further develop the aforementioned models for the design and driveability of offshore foundations. The models will be integrated into open-

source software such as OpenSees and Kratos.GHG emissions and storage in land and water management

The water- and subsurface systems play a dual role, either these systems emit GHGs or they serve as long-term GHG storage. Smart management of water- and subsurface with respect to the carbon cycle can make the difference here. Furthermore, interventions in water and/or soil may cause GHG emissions, like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Attention is increasing to develop and apply innovative measures to improve this GHG balance. The research cycle of measurements, modelling, mechanistic understanding, measures and monitoring ensures quality of the generated output.

We work together with Wageningen University, because of the obvious between emissions and uptake in water systems and near agricultural systems. On emissions in wetlands, we cooperate with Nijmegen University, VU Amsterdam and Utrecht University. Through the start of the Sustainability Research Facility (see below), the cooperation between Deltares and RIVM and Wageningen university will be strongly strengthened.

Industry partners for cooperation come from the EcoShape Building with Nature Network and include Arcadis, Boskalis, Van Oord, Witteveen+Bos and Sweco.

Deltares has the expertise required to work on this topic, with excellent knowledge on processes in water and subsurface systems, with facilities to perform the measurements and (field) experiments and tools to develop required models or forecasting instruments.

We integrate our non-carbon expertise (on water, soil and subsoil) with our expertise on GHG emissions and carbon uptake. We elaborate on existing models as well as the laboratories and field facilities. The New Delta-Lab, including the Climate Facility opening in October 2024, as well as the extension of the facilities as part of the *FTO Duurzaamheid* strengthen our in-depth knowledge and collaboration with partners.

The main activities for 2025 are:

- Development of tools for a carbon balance for water systems in the Netherlands. We aim to quantify the amounts and identify knowledge gaps.
- Carbon uptake (and emissions) of natural systems after land use change or nature development (e.g. change of nutrient load, artificial land generation etc).
- Validation of the carbon cycle in our models, through testing of those models that have carbon cycle involved (eg for algal bloom or pH calculation), but which never have been employed for calculation of GHG emissions and carbon sequestration.
- Strengthen the knowledge and policy ecosystems om carbon sequestration and GHG emissions in water, soil and subsoil.

Table 5.3 - Selection of foreseen activities in portfolio 3 in relation to the experimental and digital facilities.

	Programs and projects	Connection with facilities (both digital and experimental)
1	DUNAG, Duurzaam Nat Grondverzet voor klimaat en natuur	Delta-lab facility measurements and bio-geo-chemical field measurements Model analysis
2	POKONABO, Potentie Koolstofopslag in Natuur en Bodem	Measurement and analysis of carbon uptake in Nature Based Solutions
3	NOSE, North Sea Atlantic Exchange	Carbon effects in the North Sea
4	NOBV NOB – Veenweiden (nobveenweiden.nl)	Geotechnical field facilities regarding subsidence
5	REST-COAST REST-COAST	Modelling of salt marsh carbon sequestration
6	FTO Duurzaamheid	Integrated within the Delta-lab; links with D3D-ECO

5.2 Knowledge facilities

The Deltares **experimental facilities** play a prominent and indispensable role in the research within the Moonshot and will continue to do so. Physical experiments provide a valuable contribution to the development of knowledge needed for the energy transition and for GHG balance from water and the subsurface and is reflected in the various program portfolios and ongoing/future projects. They are essential in the value chain to validate proof of concepts of innovative solutions, to develop and validate prototypes to validate design methods and to provide test data. Major developments are foreseen in making the facilities more suitable for measurements on temperature changes and their impact on subsoil and environment. Various pilots are foreseen for 2025.

Facilities where the interaction between water, soil and infrastructure are investigated are critical for the research performed in this moonshot. Experiments are shifting more and more towards developing sustainable infrastructure required for the energy transition and understanding its ecological impact. The Geocentrifuge and water-soil flume are the most important facilities to meet these goals. An important challenge here is to update this facility to improve fit-for-purpose innovative experiments.

Another important facility is the very new DeltaLab, which will be operational from October 2024 and which allows us to combine experiments for biogeochemistry and physical chemistry in a single lab. The lab provides tests on the different parameters for a better understanding of CO_2 emission and storage, both for longer term experiments (mesocosms etc), field work (greenhouse gas flux measurements). Emphasis for the next year is the startup of this lab and start of the Facility for Applied Research on Sustainability (FTO Duurzaamheid), a collaboration between WENR, KNMI and Deltares on the measurement of GHG and related gases. It will allow us to extend our analysis of carbon storage with stable isotope characterization.

Furthermore, these experiments deliver large datasets which are linked to our models. Key technologies (software development but also AI and ML, digital twinning) are needed to properly integrate all links in the chain. The use of experimental facilities has been included in the portfolio activity tables above.

Software & Digital transformation

Dominant software development for next year are foreseen on temperature related issues, predicting effects on the environment from source to impact. These software-tools are KRATOS irt subsoil, WANDA, D-GEO pipeline irt transport pipelines. Linking Delwaq with other software to assess the effects of temperature or sunlight on the water quality is a topic that will be explored on feasibility.

Also, there will be a try-out of the RA2CE software if this can be made applicable for energy transport networks.

For GHG emissions in peat, the Somers 2.0-model will be extended and implemented within the Deltares software strategy.

On the data side, the large data requirement of DNA-analysis in meta-genomic analysis will require the extension of our data management for this type of data. This will require both storage and reanalysis, applying FAIR principles.

The interaction of this Moonshot with the Knowledge facilities is described in further detail in chapter 7. More detail about the connection between the Product lines and the Moonshot can be found in chapter 7.3 and Appendix A.

Deltares

6

Resilient infrastructure

enabling delta life

6 Resilient infrastructure

Figure 6.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the moonshot: Resilient infrastructure.

Welfare is unthinkable without infrastructure. It is an essential foundation, the underlying (infra) structure, serving civilization. Just think of in how many ways we are connected and to what extent our wellbeing relies on infrastructure in our everyday life.

What comes up? Our drinking water supply, the mobility options, our power and internet, the sewage and drainage system in our cities or the storm surge barriers at the coast? It is easy to conclude that availability and reliability of infrastructure are essential to us.

The state of our existing infrastructure is challenged everywhere by changing conditions and demands. Moreover, it has become clear that when adding, renewing or replacing infrastructure, we need to carefully take the rapidly changing societal, economic, and environmental contexts into account. For instance, we became aware that next to serving demand and economic stakes, we need to preserve and restore nature for our future well-being and prosperity. We also need to strive for total net zero greenhouse gas emissions, circular use of materials, social equality, freshwater availability and consider land subsidence. Further, we do not know exactly how and at which rate climate change effects will unfold within the desired lifetime of infrastructure, and how extreme weather conditions and natural hazards will develop. What needs to be done e.g. in anticipation of droughts, sea-level rise, or heavier rainfall events, during events, or after such events? Consequently, it has become apparent that infrastructure needs to be developed that can cope with or can be adapted to changing societal needs and changing environmental conditions. We want infrastructure to be available and safe. It should fit within the boundaries of the natural system, available space and the environment. We call this *resilient infrastructure*.

There are many parties active in this field, such as policy makers, asset owners, firms producing detailed designs, contractors, and governments, each with their own role and responsibility. Decisions about transport systems, hydraulic structures or urban infrastructure are made by our broad range of partners, stakeholders, and clients like the Dutch Ministry of Infrastructure and Water Management, Rijkswaterstaat, ProRail, the Port of Rotterdam, municipalities like Gemeente Amsterdam, Water Boards, (international) utility companies, industries, contractors, and engineering firms do. Our work mainly impacts the state of infrastructure in terms of availability and safety at optimal and acceptable societal costs and values. This applies for single objects as well as infrastructure networks and interconnected infrastructure systems. The goals and anticipated impact is achieved when our stakeholders adapt their actions, policies, decisions, regulations or standards based on our knowledge and output. In general we recognize the following outcomes:

1. Governments & regulators set standards and policies to enhance infrastructure availability and safety at optimal and acceptable risks & societal costs, enabling investments in resilience.
2. Infrastructure operators implement strategies and assessments to enhance infrastructure safety and availability at acceptable risks & societal costs.
3. Contractors and engineering consultants invest in and provide practical solutions and validated innovations that fit the implemented strategies and policies.
4. Stakeholders & public are aware of the risks and societal costs of safe and available infrastructure.

By contributing to these outcomes Deltares will positively contribute to resilient infrastructure and in the end wellbeing in society.

6.1 Research activities

We are motivated to learn from the past, consolidate our specialist expertise, and expand this by using innovative technologies and developing new tools aimed at our clients' needs and stakeholders' benefits. It is our striving to stay connected with the social and environmental context both nationally and internationally, the needs felt by the transitions, the endeavours of our stakeholders, partners and clients, the past, present and future: our history and traditions in hydraulics and geo-engineering, and innovative technologies and innovations, maximizing our positive impact for society. Greatest opportunities to achieve this impact lie in contributing through research, knowledge sharing and advisory services focusing on the following outputs:

Output 1. Accelerate decision making towards resilient infrastructure
The objective of this output is to facilitate informed decision-making towards the resilience of infrastructure. While taking account of the long-term effects of those decisions from economic, social, environmental, and technical perspectives. We help prioritization in the tremendous renovation and renewal task and support policy makers in decision making about what to invest in. We aim research at better life-cycle decisions, while acknowledging the fact that better can also mean faster and
less perfect.

Output 2. Improvement of assessment methods to evaluate resilience of existing infrastructure

The objective of this output is to quantitatively assess the resilience of a structure, network or system to enable objective decisions on measures. We know which measures/interventions at object/network/system level are effective. We know how to measure/quantify infrastructure performance & risks. We know what changes in demand and external forces effect infrastructure performance. We know what service level infrastructure should provide to enable broad prosperity in society.

Output 3. Creating new concepts and views on infrastructure design, functions and use

The objective of this output is to create concepts and views on infrastructure design, functions and use, including innovative nature inclusive & resilient solutions. Involving re-using or repurposing the existing assets, prioritising the reuse of materials, incorporating low carbon solutions, and accounting for how demands and use will change in the years to come. We put such solutions to the test using our experimental facilities, software and emerging technologies. We will include effects on surroundings and enhance acceptance and social inclusivity. We promote our forward-aimed concepts and ideas via contributions to guidelines and national and international standards.

Output 4. Smart use of large data sets and emerging technologies, including data-led predictive asset management

The objective of this output is to stay up to date and make smart use of large data sets that are becoming available and emerging technologies ourselves and support others in doing so. Smart here means that we make full use of our existing expert knowledge and tools. We develop improved experiments, software and tools for data and information handling for performance and risk assessments of the state and use of infrastructure objects and systems, spatial planning and decision making by our stakeholders: monitoring, collecting, evaluating, structuring, processing, subtracting, and visualizing the essence of data. An important field of application is data-led predictive asset management, utilizing intensified monitoring of the object and system state and
conditions.

While risks with different types of infrastructure are specific in their technical nature, the methodologies can be the same for all types, allowing for the development of generic methods and tools, providing synergy between infrastructure types. Therefore, parts of our activities are related to specific infrastructures and contribute to multiple outputs and outcomes. Other activities are dedicated to specific outputs. The figure below shows the contribution of the various activities to the output and outcomes.

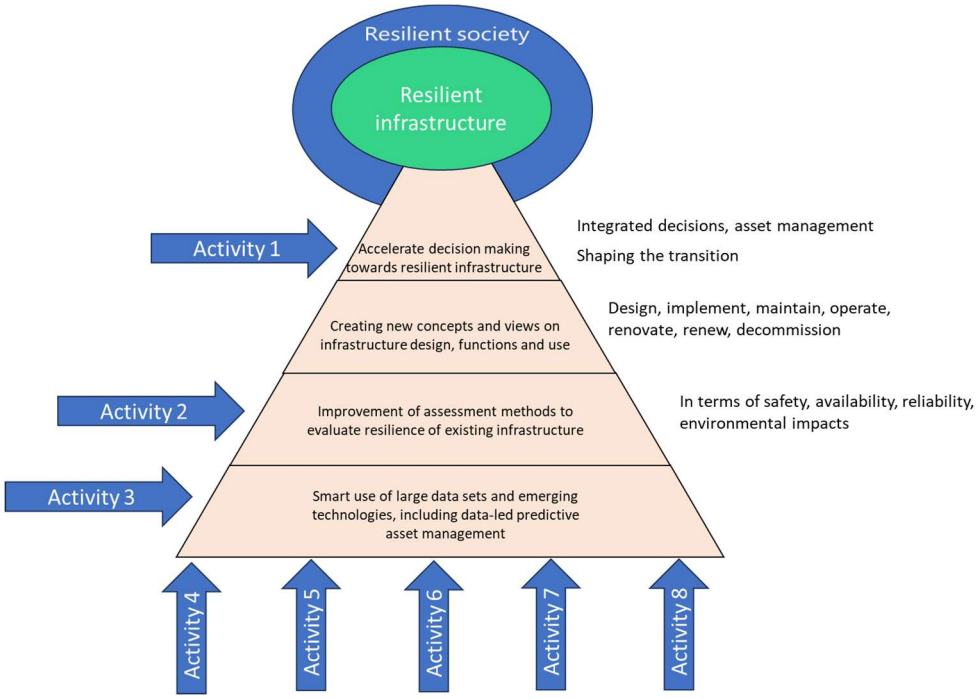

Figure 6.2 - Activities leading to output & impact.

We have prioritized activities that have a societal urgency today. Such as the activities wooden pile foundations that is part of the current Regeerprogramma. Or the activities in preparation of the 2025 critical infrastructure stress tests (Deltaprogramma vitaal & kwetsbaar). These activities are expected to be validated in practice shortly. We have prioritized activities on dataled predictive asset management as they can truly change the outcomes of decisions on the renewal and renovation challenges and in asset management operations. We have prioritized activities that are closely related to our stakeholders needs, such as the activities on hydraulic structures and ports. With these activities we enable Rijkswaterstaat and Port authorities to optimize their operations, to maintain their license to operate and to be prepared for future challenges. In general activities balance between integrative knowledge and detailed technical aspects. And between exploratory research with a longer timespans towards impact and activities carried out in close cooperation with our stakeholders to validate our research. Besides these activities, in 2025 we will further enhance our impact pathways by providing an outlook on the scientific state of the art and through policy and stakeholder engagement.

6.1.1 Critical infrastructures

We facilitate better decisions on critical infrastructures in urbanized environments (Activity 1).

In urbanized environments infrastructure developments are closely related to societal transitions such as housing, the energy transition and climate adaptation. In this SITO IS activity we want to answer the following knowledge questions that support balanced choices for vital infrastructures in urbanized areas:

- What preconditions do future perspectives impose on today's decisions?
- What preconditions does the existing “grey” infrastructure impose on the future?
- What tipping points do we see and need further quantification?

- What is the usefulness/ necessity/ feasibility/ effectiveness of different blue-green infrastructure scenarios at different scale levels?
- What can/ cannot work at delta scale, regional scale, city scale, district scale etc.?

In 2025 we will offer combined design & engineering perspectives that decision and policy makers can use in their challenge for a resilient critical infrastructure in urbanized areas cases. We will connect these perspectives to one or more cases and stakeholder. We base our activities on the results of the Deltaprogramma that distinguishes 13 Vitaal & Kwetsbare functions. Also, we consider the work of the NCTV and will link to the Critical Entities Resilience guideline. We learn to provide decisionmakers with overviews of pivotal decision moments and clear pathways. In these actions we take into account future changes in today's decisions and the impact of today's decisions on the future solution space. The societal outcome of these activities are better decisions by the involved stakeholders on the safe & effective operation of infrastructure taking into account climate change and societal transitions at hand. This activity integrates output of various other activities with respect to vital infrastructure (primarily SITO-PS "Kennis voor Wateroverlast – Vitaal en Kwetsbaar & bovenregionale stresstest", Municipality of Amsterdam "vulnerability of (cascading) critical infrastructure vulnerability).

6.1.2 Resilience of infrastructure

We evaluate the resilience of infrastructure to enable broad prosperity (Activity 2)

Our society increasingly demands to include other factors than economical and safe operation principles in decision making. Typical examples are impacts on nature and the environment, health impacts or considerations of equity. By applying broad prosperity indicators in the performance metrics of infrastructure we are able to assess available and safe solutions at the lowest societal costs. In 2025 our work on performance metrics will be implemented and tested with various asset owners. The goal is to achieve more effective and harmonized performance assessments for improved comparability and interchangeable methods and tools. The results of this activity is further operationalized through RA2CE.

The Horizon Europe project CLARION Deltares develops a Multimodal Hinterland Resilience Model (MHRM), which integrates road, rail and waterway networks, and which aims to identify hotspots of climate-related threats. This allows us to assess the climate resilience of the transport system as a whole and the impact of disruptions. The MHRM provides valuable insights for infrastructure managers when making decisions and improves the efficiency of the transportation system through infrastructure adjustments. In 2025 CLARION will further elaborate on the interconnectedness while integrating various infrastructure transport networks into RA2CE.

Basis for the Multimodel Hinterland Resilience Model is amongst others the Digital Twin Waterway's. Over the past few years the digital twin waterways platform was co-developed within the context of public-private collaborations (PPS) with funding from TKI Deltatechnology, TKI Maritime, SmartPort and contributions of a growing number of partners. The digital twin waterways allows inland shipping entrepreneurs and waterway managers to explore and use different scenario to make informed decisions. In 2025 we will continue the work of the TKI TRANS2 project on climate resilient inland waterway transport (together with

a.o. SmartPort, Port of Rotterdam, RWS and inland shipping companies) and disseminate our knowledge via the digital twin waterways and PIANC guidelines.

To quantitatively assess the resilience of a infrastructure network or a multimodal system Deltares developed RA2CE. In 2025, the RA2CE tool will undergo further advancements in the modules uncertainty, adaptation, and inclusion as well as the implementation of broad prosperity indicators. We will also further work on its application in a multimodal context. Additionally, we will investigate how RA2CE can be used for energy infrastructure networks following up on our activities in 2024. To develop this context, the spatial and intermodal effects shall be further studied and integrated into RA2CE to provide decision-makers with a risk-informed planning perspective. Also we will further align RA2CE with the new CER regulations to ensure implementation of our work. These developments aim to enhance the tool's versatility and effectiveness, ensuring it meets the evolving needs of various sectors.

This activity is both developed and applied through a broader projectportfolio apart from SITO IS: in Horizon Europe projects (Clarion, MIRACA), in DPRA (Deltaprogramma Ruimtelijke Adaptatie), SmartPort, World Bank projects and the Rijkswaterstaat programme on Klimaatbestendige netwerken and in TKI projects (Trans2, Path2Zero). The desired societal outcome of these activities is the implementation of improved long term strategies and assessments methodologies by infrastructure operators. To enhance implementation we disseminate our work in guidelines and standards (PIANC, PIARC).

6.1.3 Technologies for data-led predictive asset management

We provide technologies for data-led predictive asset management (Activity 3)

While risks with different types of infrastructure are specific in their technical nature, the risk-based fashion of implementing monitoring-based condition monitoring is the same for all types, allowing for the development of generic methods and tools, providing synergy between infrastructure types. In order to provide asset owners with appropriate methods and tools as soon as possible, fundamental developments need continuation in order not to develop ad-hoc solutions for different challenges and clients. The method development needs to focus on risk-informed decision making, handling monitoring data with uncertainties, as well as translating monitoring output into reliability and risk estimates.

The tool development needs to provide a sound basis for (monitoring) data, a modular setup for using the data with different types of interpretational techniques, and (visual) representation of meaningful output to decision makers, for instance trough digital twins. As there are already good examples of Digital Twin technology in our sector, the development of methods and tools can deliver showcases of combined existing technology (sensoring/AI), applied in real cases.

In 2025 we will work on the following cases and workflows:

- By integrating various types of subsurface data in data-driven and reproducible workflows subsurface properties and characteristics can be properly modelled (subsurface toolbox). The workflows employ AI algorithms to model subsurface

properties. These developments allows more effective data acquisition, leading to improved quantification of soil & groundwater related risks on infrastructure construction and asset management.

- Deformation monitoring of railway embankments allows to mitigate risks of embankment failures and derailment of trains through early warning and triggering the necessary maintenance and/or (temporary) restrictions in train traffic. Closely related is the RESET research program for ProRail on Railway embankment stability.
- Reinforcement Learning can be used to efficiently balancing risk, cost, and performance indicators, to optimize decision-making for engineering asset management. For instance on quay walls. Closely related is the ongoing NWA LiveQuay (2023-2027) project which aims to improve decision-making to maintain the current safe operational conditions of quay walls by assessing the remaining useful life span and the potential need for measures.
- For hydraulic engineering structures and multifunctional water barriers it is crucial to include changes in the behaviour of the water system and to combine them with asset information. In 2025 we will work on a TKI initiative on a climate adaptive Digital twins which can help asset managers in their predictive asset management.
- Data fusion between reconstructed shear wave velocity profiles and geological data along the Hanzelijn, including the addition of fibre optic-data will allow for more accurate embankment characterization and vibration predictions and stability assessment along railways. These developments take place under the ongoing STEM, RESET and Horizon Europe Rail4earth programs.

In 2025 we will realize these development in joint TKI settings to force possible breakthroughs to roll out this technology more widely. Moreover, we will include our in depth know-how of assets and make use of the digital twins in other studies in collaboration with our stakeholders. Also these developments are validated in the workflows of infrastructure managers, aside the ongoing project portfolio (RESET, STEM, KPNK, SMARTPORT). While the results are transferable to other infrastructure also internationally. With the outcome of the asset owners adopting the development tools and methods, the impact will be continuous safe operation of infrastructure and cost savings by deferred investments in replacement and retrofitting.

6.1.4 Renewal & renovation of hydraulic structures

We help to prioritize the renewal & renovation of hydraulic structures (Activity 4)

In the Netherlands, hydraulic structures have been built with an expected lifespan of up to 100 years. A large proportion of these structures, or the concrete, steel or wooden parts thereof, are nearing the end of their lifespan. For instance currently 80% of the large retaining walls in The Netherlands are at the end of their design lifetime. These quay walls are applied in harbours, canals, locks, viaducts, and bridges. The investments associated with their renewal are often substantial. Asset managers therefore want to be able to substantiate and justify their decision-making in this regard as transparent and future-proof as possible. Is it preferable (from an economic point of view) to extend the lifetime of their infrastructure, or is immediate renewal or renovation the most advantageous?

The Knowledge Program on Hydraulic Structures (KpNK) conducts research into factors that determine the remaining lifespan of the civil and movable parts of hydraulic structures. In 2025, the SITO IS program will focus on:

- Extending knowledge om how to take into account the impact of uncertain climate change effects (in particular, extremely high or low water) in decision-making on adaptive strategies for renewal and renovation.
- Based on actual monitoring data (e.g. from the demolition of obsolete structures) , enabling the determination of a more realistic timespan for reaching the technical and functional end-of-life. Specific attention is on the lifespan of sheet pile walls & anchors.
- Methods to take into account future (climate, socio-economic and policy) changes into today's decisions, and the impact of today's decisions on the future's solution space.
- Developing (economic) knowledge for developing sustainable, 'constructable' and feasible solutions that make the renewal and renovation task manageable.

KpNK is a collaborative initiative of the knowledge institutes Deltares, MARIN, TNO and asset manager Rijkswaterstaat. The results of our work is tested and validated in Rijkswaterstaat projects (locks, sluices, weirs, quay walls etc) and leads to short term impact in the prioritization of these projects. It leads to improved guidelines and standards through involvement in various CROW & NEN committees. Through these activities we learn to provide decision-makers at Rijkswaterstaat & the ministry to bridge the gap between longer term strategies and operational decisions and to provide overviews of pivotal decision moments and pathways. These methodologies are generic and find their application into other areas as well. This activity integrates output of various other SITO IS activities from a large portfolio of activities both for Rijkswaterstaat (SITO PS, SPA, Spoedadvies) as well as other stakeholders (TKI Kakalawa, NWA livequay, SMARTPORT, Municipality of Amsterdam).

6.1.5 Resilience of port & waterway infrastructure & operations

We enhance resilience of port & waterway infrastructure & operations (Activity 5).

The SITO IS activities in 2025 focus on developing domain knowledge for safe, sustainable, nature-inclusive and (climate) resilient port & hinterland infrastructure and operations at asset and network level (inland waterways, fish migration routes).

- Climate adaptation of coastal structures. With uncertain sea level rise, it is wise to adapt coastal structures, rather than ignoring potential future threats or constructing coastal structures for the worst-case scenario (leading to un-economical designs). In 2025 we finalize our work of previous flume tests leading to probabilistic sound insights in adaptation measures for coastal structures.
- Smart & sustainable port sediment management: Sediment management in port is key for the assurance of transport functions, adaptation to climate change and sustainable ecosystem quality. In 2025 we will publish methods to assess climate change effects on port sedimentation (case Port of Rotterdam) and start on new initiatives on the use of fibre optics for sediment monitoring Together with Rijkswaterstaat we look into the explicit risks of dredging in canals leading to unwanted risks to the surrounding infrastructure and environment.

- Lock operations: Over recent years droughts in the Netherlands and Panama have led to large disruptions in shipping operations and almost threatened strategic freshwater resources. These droughts will only increase in frequency and severity in the coming decades. In 2025 we will focus on new initiatives on coordinating operational forecasting systems for salt management and decision support systems at shipping locks together with partners RWS and Panama Canal working towards a common approach for salt transport models linked to shipping movements and mitigation strategies for operational decision making based on Delft3D-FM models and FEWS.
- Safe and efficient shipping operations: nautical safety on the North Sea has increasing attention, especially since the incidents with the MSC Zoe and Julietta D. With the increasing activity and infrastructure on the North Sea this will become more urgent. Focus is on awareness on nautical safety at North Sea together with partners: RWS, Coastguard, MARIN, TU Delft towards operational predictions of nautical safety at North Sea based on Delft3D-FM models from RWS and AIS data.

We will enhance the societal outcome through collaborative projects to ensure uptake of our developments with Rijkswaterstaat in SITO PS, SMARTPORT, in TKI's CLIMACS (Van Oord, TU Delft), TKI FOSEM and TKI PRISMA3, through scientific publications and via open source software (C-SUMO, Delft3D-FM, FEWS). Also Deltares participates in CROW & PIANC working groups were results are put into guidelines and standards. In 2025 we validate our work via academic publications on climate resilience assessments on ports (Sohar).

6.1.6 Storm surge barriers

We enhance decision making on storm surge barriers (Activity 6).

The Netherlands has a pioneering position with the construction and use of storm surge barriers. We have unique knowledge about these objects. However, it also means that the Netherlands is the first country to encounter the disadvantages of these barriers in practice, including maintenance issues. Insights into sea level rise have changed and assessment criteria under the 'Omgevingswet' have become stricter in recent years. These are signals that action must be taken. In this activity we will work on finalizing the knowledge dossiers of all existing storm surge barriers in the Netherlands. Based on this we will define critical technical questions related to the tipping point within adaptation pathways (MS1). This will lead to realistic limits of possible changes to current storm surge barriers. Also there are specific topics to better understand such as the vibrations of gates/barrier elements. As we are currently performing physical scale model tests for the Oosterschelde barrier (RWS) we need to prepare for knowledge gaps that arise from the current tests and prepare additional (model) tests on other existing barriers. Activities will be disseminated through journal papers and ISTORM involvement.

This activity leads to better informed decisions regarding asset management of storm surge barriers by Rijkswaterstaat. The result flow into the dynamic adaptive pathways for the Southwest Delta and Rijnmond Drechtsteden. We will make this work through ongoing collaborations in the NWA proposal SSB Delta and model tests on the Oosterschelde barrier.

6.1.7 Performance of pipeline infrastructures

We assess the performance of pipeline infrastructures (Activity 7).

Recent national forecasts for municipalities, drinking water companies and waterboards show that an enormous increase in the renewal of sewage systems and drinking water infrastructure can be expected in the coming decades. Delayed renewal potentially leads to downtimes and incidents and consequently to decreased availability of drinking water and sanitation. Meanwhile, the energy transition and further urbanisation require extensive underground investments. These investments lead to increased risks due to installation of cables and pipelines closer and closer to existing buildings and infrastructure. In recent cases this caused scope changes and unforeseen costs. The risks will grow in upcoming years due to the increasing investments in the energy transition.

Deltares wants to make impact on the resilience and sustainability of pipeline infrastructures. Our approach targets multiple levels, from operators to managers and policy makers. This ensures comprehensive impact across the sector where there is a big gap between the decision makers and the professionals.

In 2025 we will work on awareness and to foster community engagement with our main stakeholders. We will develop methodologies for probabilistic pipeline assessments taking into account combined infrastructures, incident analysis and failure mechanisms, closely related to the current decision-making context of the infrastructure owners. These developments will be the starting point for joint activities with the sector on pipeline performance assessments to guarantee infrastructure availability and to reduce downtime. Input to these assessments are innovative leak detection methodologies, supported by extensive experimental datasets to test, benchmark, and validate these techniques. In order to reduce constructions risks and hindrance activities on Horizontal Directional Drilling techniques is necessary in collaboration with the NEN3650 community.

The intended outcome of our activities in 2025 is to create awareness on strategic levels, as our current portfolio succeeds in operational outcomes but lacks strategic implementations. We will do this trough community engagement (CAPWAT, NEN, RIONED and STOWA). As our activities include improving tools for detailed design (WANDA, D-Geopipeline) that are currently in use by asset owners in their operational decisions, our work improves decision making and fill this gap. We will set standards on several methodologies and solutions (NEN) in order to improve practical implementations.

6.1.8 Risk information on piled foundations

We provide risk information for policies and standards on piled foundations (Activity 8).

The SITO IS activities in 2025 focus on developing domain knowledge for safe, sustainable and resilient quay walls and foundations.

- Around 450.000 houses and many civil structures face foundation issues. A wicked problem due to the diverse nature of the damages, complex procedures and unclear legal responsibilities. The RLI advice (February 2024) gives guidance to accelerate

on an effective approach. In 2025 Deltares carries out several activities in order to contribute to the necessary outcomes of the RLI advices. We want to better understand the nature of damages due to drying and wetting. Together with TKI Bouw and Techniek and Waterboards we explore the possibilities of non-destructive inspection techniques and fundamental insight in the degradation process of timber piles using monitoring data. These insights, together with other data sources (satellite, socio-economic data) feed the risk information towards better policies and standards on this challenge. Meanwhile foundation re-use will be explored. The construction industry significantly contributes to CO2 emissions. Decarbonization is a vital strategy, focusing on more efficient designs that reduce the volumes of concrete and steel used. However, the reuse of existing foundations is the most sustainable option.

- To facilitate these analysis Deltares develops open source KRATOS numerical software to support probabilistic analysis for these structures.

Results of these activities are implemented into CROW guidelines which are the Dutch standards for construction and maintenance activities on these type of structures. Furthermore results support the decision making on hydraulic structures (KPNK), quay walls and bridges in Amsterdam and in the Rotterdam harbour area. Furthermore results will improve the risk information for house owners, municipalities and policy makers (RLI advice).

6.2 Knowledge facilities

The interaction of this Moonshot with the Knowledge facilities is described in further detail in chapter 7. More detail about the connection between the Product lines and the Moonshot can be found in chapter 7.3 and Appendix A.

Deltares

7

Knowledge facilities

enabling delta life

7 Knowledge facilities

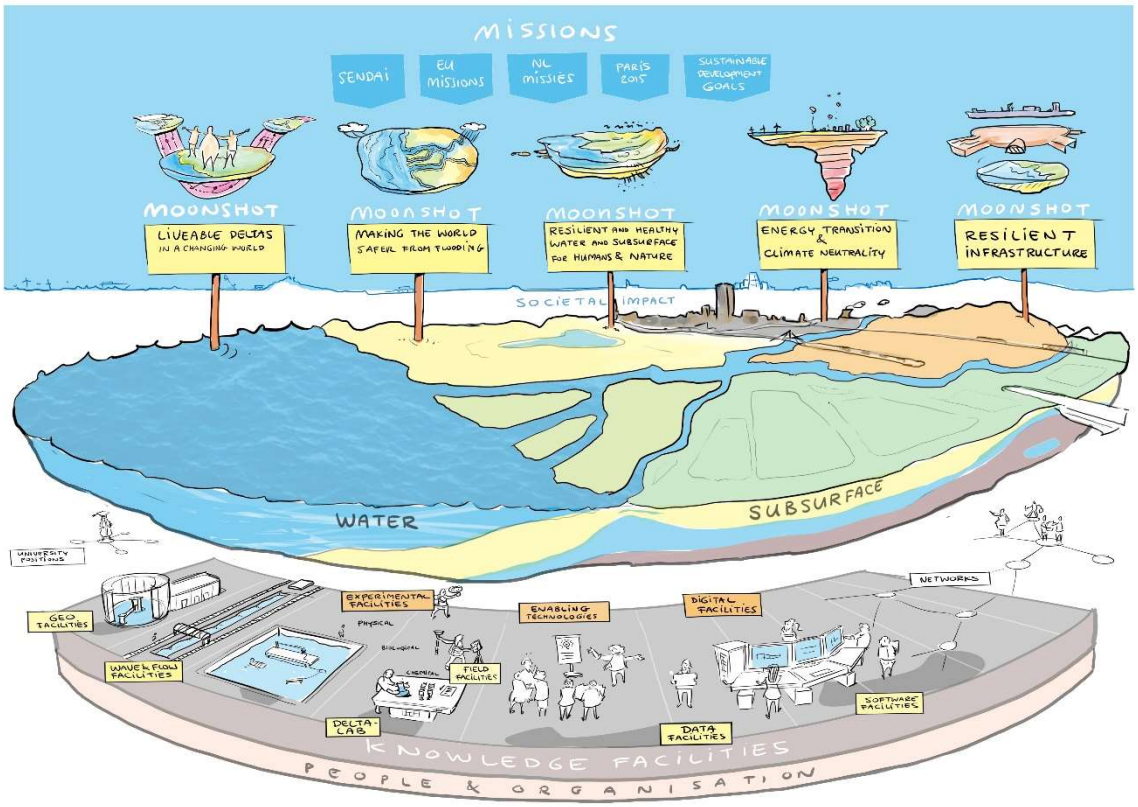

Figure 7.1 – In this Figure the missions and examples of research fields within the water and subsurface system are shown for the for the Knowledge facilities.

7.1 Introduction

Our knowledge facilities are fundamental to the identity and core business of Deltares as an applied knowledge institute. They thus comprise a crucial part of realizing our mission Enabling Delta Life. In our knowledge facilities, the knowledge, experience and learnings of our experts are validated and converted into usable tools, software and experiments. They are indispensible for arriving at workable, scalable and evidence-based solutions.

The Knowledge Facilities comprise of five facilities, each with key characteristics:

Properly managing, analysing and applying data can further help us solve complex issues. The digital revolution is challenging our organization in maintaining our position as technical knowledge provider. With ***data & data science*** (paragraph 7.2) we tackle complex water, subsurface and infrastructure challenges. We apply FAIR ((Findable, Accessible, Interoperable, and Reusable) data management. We develop data pipelines and apply data-driven techniques to develop new information products and improve our software and models that contribute to keeping delta regions around the world liveable and safe.

Software is a key product for Deltares and indispensable in developing optimal solutions for all our Moonshots. We manage, maintain, and continuously enhance our software and models (paragraph 7.3). This includes the software and models that are mission-critical for the Dutch government, particularly the Ministry of Infrastructure and Water Management and water boards. Examples of our software & models include flood and drought warning systems, models showing the amount of groundwater, river discharge or subsurface stability, software for design and performance monitoring of engineering structures and software for assessing water quality and ecosystems.

Enabling Technologies (paragraph 7.4) tests and reviews technological innovations in the field of computational technologies, data science and (remote) sensing. Think of tests, experiments and reviews of innovative technologies, which are of low Technology Readiness Level, but have the potential to have a huge impact on the aspired future outcomes of the moonshots. Examples are AI-driven models enabling computational speed-up with a factor of 10.000 or more, Digital Twins of levees which offer up-to-date information for maintenance and security, globally available remotely sensed water levels.

Our unique ***experimental facilities*** (paragraph 7.5) are an integral part of our knowledge base. We test our knowledge, calculations and solutions in these experimental facilities. The 300-metre-long Delta flume where we can simulate waves of more than 4.5 metres high is world-famous. The same goes for the innovative GeoCentrifuge in which we reduce processes in the subsurface that in reality take years to hours, necessary to build a road or tunnel. To adapt hydraulic structures to changing conditions along coasts or at ports or to build new ones for that purpose, it is important to test them before the build. What is the optimal design for the conditions in place? We do this in our six wave facilities. With our Geofacilities, we perform research for issues related to the subsurface. We study the effects of human interference, for instance, if you want to build or improve a tunnel or a road. Experiments also enable us to study situations and effects that might occur in the future. In the new Deltalab we explore possible solutions for reducing greenhouse gas emissions, sufficient space and use for dredged material and the presence, spreading and effects of pollutants. Our Field Facility offers state of the art technology for surveying and monitoring the subsurface, for example for heat storage or assessing rail embankments.

The Knowledge Facility '***University Positions & Networks***' (paragraph 7.6) serves the connection with fundamental research through the support given to research chairs and active participation in highly relevant professional networks.

Starting points for programming (prioritizing) activities under the knowledge facilities are their contribution to realizing the moonshots (mission-driven), signalling and responding to new technologies and innovations (technology-driven, low Technology Readiness Level which might have a high impact) and maintaining our strategic facilities (as they are vital for the Dutch knowledge infrastructure).

7.2 Data & data science (digitalisation)

Data is one of the valuable assets in our, scientific, research. The main objective of the Deltares Data Knowledge facility is to further advance the quality and usability of, scientific, data and stimulate the (re)use of data both for innovative solutions and knowledge dissemination to a broader audience.
We do this by our contribution to Large Scientific Research Infrastructure (LSRI) initiatives like DeltaEnigma (ΔEnigma) and DigiLab. In these initiatives Deltares will contribute on standardization of data formats, data quality definitions and policies, defining and adopting metadata-models as a standard, enhance the interoperability and provide user support and training.

DigiLab is a collaborative platform of the TO2-insititutes, led by Deltares, that enables digital collaboration within a virtual research environment. It is a shared digital facility in which researchers can collaborate with governments and market parties flexibly, efficiently and securely. We gain access to each other's data, algorithms, models and computing power, while respecting data sovereignty. The federated platform also makes essential high-quality data accessible for more effective advice to government, industry and civil society organisations. In DigiLab we will work closely together with other leading research institutes.

For ΔEnigma, a Large Scientific Research Infrastructure which supports the interdisciplinary character of the research field at the interface of geomorphology, hydraulics, ecology and engineering, Deltares will set-up the data-infrastructure according to state-of-the-art techniques in collaboration with SURF. Deltares has the ambition, by combining and implementing standardization and the data infrastructure at this scale, to contribute to a national Large Scientific Research Infrastructure which will set an example in data-sharing.

All Deltares Moonshots rely on, and produce, valuable data(sets). In 2025 the Data Knowledge facility will facilitate and coordinate easy access to a number of these high value data sets. For datasets which are well managed by an external organization we will set-up a structural connection to these datasets both on management/governance and infrastructure level (by providing and managing pipelines). Standards and policies will be set-up for the data produced in the Moonshot initiatives to be able to share these valuable datasets according to adopted standards. Catalogues, compliant to these policies and standards, will be created to store the metadata of these datasets which will make the datasets accessible and interoperable in the organization.

To disseminate the knowledge, we create based upon these important datasets, we will further develop and maintain the IT-infrastructure building blocks of ΔEnigma and DigiLab. Utilizing these building blocks, we can create a visual representation of knowledge and its impact derived from these important datasets. This activity will contribute to all the Moonshots, with a focus in 2025 to Moonshot 'Liveable delta's in a changing world', 'Making the world's population safer from flooding', and 'Resilient and healthy water and subsurface systems for humans and nature'.

Deltares actively collaborates and co-creates with external partners. Deltares is an active partner in Digishape and NMDC and actively pursuing collaboration with its partners in fields

of AI and computational technology. We foresee that working with external parties on data will expand and intensify. Therefore, we're developing the infrastructure and applications for collaborative data in co-creation projects. In combination with fostering partnerships with external stakeholders, we aim to create a robust ecosystem that enables efficient sharing, analysis, and utilization of the data.

The Deltares Data Facility is also the fuel for the structural embedding of data science, artificial intelligence and digital twins in our research. In 2025 we intend to participate in the AI4Water ICAI[4] Lab initiative. The establishment of the AI4Water ICAI Lab will help the Dutch water sector cement its leading position in solving water issues, which is rooted in leveraging the latest technologies and unparalleled interaction among all stakeholders. AI4Water will be an academia/public/private collaboration that will employ researchers delivering cutting-edge innovation, while facilitating a rapid transition from theory to practice. AI4Water will bridge the gap between the water sector and the forefront of AI technology by also providing training and resources to professionals and stakeholders with its strong emphasis on knowledge utilization.

Now that our data management improves, our cloud infrastructure is largely in place and our organisation of software development is in transition, we learned about and want to further improve our innovation management. In cooperation with the Enabling Technologies Program, we analyse our working process through the different TRL levels and find ways to make it even more effective. We experiment with different working forms to activate and focus the creativity and innovative power of experts from Deltares and partners to challenges that come up from our Moonshots. We connect teams and working processes to each other to make sure that new knowledge and technology flows towards the software product teams and the projects that contribute to moonshots. And we offer our experts training programs to strengthen their skills on digital technologies and on co-creating with partners.

7.3 Software

Deltares' software, most of which is open-source, has been world-leading in several application areas for decades and an important part of our knowledge base. In order to maintain this position our software is continuously upgraded and innovative solutions regarding computational technology, cloud computing and data driven modeling are being tested and integrated with new applications. Moreover, we aspire to develop and maintain the software much more in co-creation with others in order to have our software developments answer the demands and needs of our stakeholders and the broader user community.

We organized our software development in 5 Product Lines:

1. Geotechnics and Flood defences.
2. Hydrology.
3. Hydrodynamics & Morphology.
4. Water Operations.
5. Water Quality & Ecology.

[4] ICAI = Innovation Center for Artificial Intelligence

All product lines have developed a vision and roadmap for the coming years which has been connected to the objectives of Deltares' Moonshots. In figure x the relationship between the Product lines and Moonshots is shown. In Annex A the contributions to the Moonshots is presented in more detail.

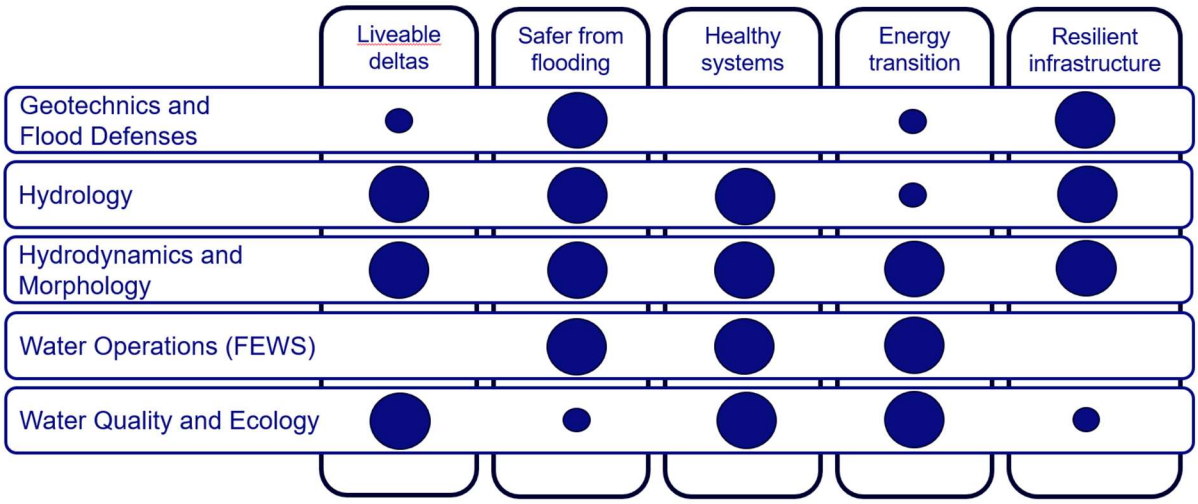

Figure 7.2 - Relationship between the Product lines and Moonshots.

7.3.1 Geotechnics and Flood Defenses

Geotechnics is a field that is essential to a wide range of relevant societal topics such as; assessing the design, stability and resilience of dikes and their revetments, safe foundations for windmills at sea, safe and sustainable quay-walls, and sustainable and reliable underground infrastructure.

We divided the activities in four focal points:

1. The further development of a computational geotechnics analysis platform, based on the open-source application KRATOS in partnership with CIMNE. Initiated in 2024, this platform is becoming a central tool for numerous applications, with plans to broaden its functionalities and use cases in 2025 with special focus on soil-structure interaction and soil-heat-structure interaction.
2. With RWS/ I&W / HWBP as major client/partner, the software to assess and design flood defences has been a major focal point. This includes tools in the Embankment Suite (D-Settlement, D-Stability, D-Geo Flow), DiKernel for revetments, and cost optimization tools like KOSWAT and VRTool.
3. Providing reliable tools (D-Series) to support and implement safe design standards related to foundations, sheet piling, pipelines, etc. In 2025, we plan to integrate the latest building standards into our software and start updating older components with a KRATOS-based kernels.
4. The assessment of resilient networks: products like RA2CE help to quantify resilience of critical infrastructure networks (e.g. road networks), prioritize interventions and adaptation measures and select the most appropriate action perspective to increase resilience considering future conditions. What could be considered a pilot in 2024 will be developed toward a real product in 2025.

7.3.2 Hydrology incl. groundwater

The product line Hydrology develops and supports an open-source Hydrology Software Suite that helps hydrologists study water security more effectively and gives a better understanding of complex relationships and processes in hydrology. The Hydrology Suite includes:

- Interoperable computational engines, reflecting the domains of the hydrological cycle: Wflow, RTC-Tools, Ribasim, Modflow6.
- Tools for fast and reproducible model building and simulation: HydroMT, iMOD.
- Better decision making by interactive planning tools: FloodAdapt, Delft-FIAT, Climate Resilient City Tool, Climate Stress Test Toolbox.

Our main focus for 2025 is to further develop the integrated Hydrology Suite by connecting the computational cores with one another. It is necessary to work towards an integrated instrument because the challenges surrounding climate change are becoming increasingly complex and can no longer be approached from a single domain to find solutions. Examples include saltwater intrusion due to rising sea levels, where the interaction between groundwater and surface water must be modeled in a connected way (coupling Wflow – MODFLOW 6). In drought related studies, it is essential to study the water supply, water demand, and water allocation in conjunction with one another under different climate and socio-economic scenarios (coupling Wflow - Ribasim). To assess the impacts on water quality under these circumstances, we will also work on integrating water quality modules with product from the product line WES. The main activities for 2025 will be focused on:

- Coupled computational kernels Wflow – Ribasim
- Coupled computational kernels Modflow – Wflow
- Online coupling surface water – water quality: online coupling Ribasim – Delwaq or an alternative approach namely for salinity modelling (to be decided with most important users and clients).

By implementing this integrated approach in our software, we will have a unique set of tools with which we can further strengthen our unique position in the field of integrated studies. And because the software is open source, we make an impact by allowing others to immediately benefit from our knowledge.

7.3.3 Hydrodynamics and Morphology

The Hydrodynamics and Morphology (HDM) product line includes a number of major software products, including D-HYDRO suite, SWAN, XBEACH, SFINCS, WANDA. The genesis and scope of these products differ. For example, D-HYDRO suite and SWAN are products that build on decades of Deltares knowledge and software. They are used in a wide variety of Deltares projects, and moreover, they are part of the critical software for RWS in its primary tasks. In contrast, SFINCS is an example of a software product that is much younger, and mainly developed for and with international clients and partners.

In summary, the agenda for the HDM product line for the coming years is as follows:

- Address the technical debt in D-HYDRO suite so that this software product becomes future-proof, and

- Establishing an overarching architecture that will enable the various products within the HDM product line to continue to be developed and deployed together.

Making D-HYDRO suite future-proof is the biggest challenge. Extensive capacity is needed to rejuvenate and renew this suite of tools where necessary, while the continuity of the models created from this software must be guaranteed. The activities in 2025 from the HDM product line are largely focused on this. We do this in close cooperation with RWS and DGWB and the Water Boards. Prioritisation in the work is determined by consultation with these partners and in alignment with the Moonshots. Funding for the work within the HDM product line comes from various sources. From SITO-IS, among others, experiments are funded for numerical and software engineering solutions to significantly reduce the computation time of D-HYDRO suite.

7.3.4 Water Operations (FEWS)

Within the product line Water Operations we develop and maintain the software-suite for Delft-FEWS that efficiently handles large amounts of forecast data, integrates the latest observations with the most recent meteorological forecasts, and provides for consistent data quality, standardized work processes, visualization, and reporting. Delft-FEWS is suited to support a broad range of applications, such as day-to-day operational management, real-time control, flood forecasting and warning, water quality monitoring, reservoir management, hydropower, navigation, groundwater, droughts, and dike strength monitoring.

Our Long-term vision includes expanding our products to use AI/ML techniques and new data platforms (e.g. data lakes). In 2025 we will extend the amount of data exchange possibilities via web services, an easy way of integrating python and coupling models via the BMI interface. This will be beneficial for several Moonshots which are in need of coupling models.

In 2025 we will develop a meteo-module able to apply bias correction and downscaling rainfall observations from ERA5 and satellites and forecast products (GFS, ACCESS-G, ECMWF IFS). By using existing techniques and explore training new AI/ML models, multiple data sources can be combined to enhance e.g. drought and flood forecasting. Connecting to Earth Observation (EO) data lakes is another activity in 2025. This will contribute greatly to the objectives of Moonshot 2 and 3 to be able to timely warn stakeholders and implement the right approach to disaster management.

7.3.5 Water quality and Ecology

The product line ‘Water Quality and Ecology’ develops software that contributes to solutions for water quality related environmental problems, ecology and biodiversity. The software is suited for both long term policy tasks and operational questions.
In 2025, the product line ‘Water Quality and Ecology’ starts innovations in ecological impact modeling, developing ecological applications for NBS-dynamics and introduce Agent Based Modelling in particle modelling. It allows us to get a better understanding of the impact of man-driven measures, but also of which set of measures/scenarios result best in achieving the objectives of the water system. This will further contribute to the efficiency of Nature Based Solutions which are a very important concept in Moonshots 1, 2 and 3.

In addition, WES continues in innovating the present model suite for Water Quality to make it faster and less dependent on very complex hydrodynamic models. This allows us to model many scenarios relevant for the moonshots and which is currently not possible due to the long run times.

Lastly, we will integrate our modeling suites with those of HYD to arrive at integrated river basin modeling from source to sea, which contributes to our understanding of the source and fate of pollutants.

7.4 Enabling Technologies

The Program Enabling Technologies 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 programs. Facilitation will take place through co-opted projects. Inspiration is generated through educational and networking activities. Since the program 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.

The innovations in Enabling Technologies will help drive its impact by enabling speed-up of modelling and data analysis, improve data sets and parameter estimations and increase the scale of our solutions. These are all in high demand by our clients. The program 'Enabling Technologies' is structured around four enabling technologies: Computational Technology, Data Science, Sensing & Monitoring and Earth Observation. Taking stock of innovations within these technologies, it focusses on testing and prototyping applications supporting Deltares' missions by enabling:

- Decreased modelling lead time – i.e. how to shorten the time needed to set all steps in the modelling pipeline, from data acquisition, through model set-up and analyzing model results.
- Increased computational speed up – i.e. how to significantly accelerate computations either through ICT-technology, emulation or data-driven solutions.
- Increased automation and scale-up of data-acquisition from local to global – i.e. how to increase scale in measuring and processing sensor information while improving spatial and temporal resolution.
- Increased value of information in sensing and monitoring – i.e. how to improve accuracy, precision and measure relevant parameters at systems level.

Activities 2025

Based on the goals and ambitions of the Moonshots we will develop a detailed planning of the pillars on Future Modelling (Computational Technology), Data Science, Future Sensing (Sensing and Monitoring) and Earth Observation. Two topics will get extra attention:

1. Innovations in AI and ML

   Artificial Intelligence and Machine Learning are considered to be major technological drivers in our field of expertise. Over the last couple of years, the program Enabling Technologies has invested in Hackathons, experiments and testing of various AI and ML-approaches, such as: Physics Informed ML, Hybrid Modelling, Generative AI and Agentic Workflows. These experiments have resulted in keeping an updated insight on the capabilities of state-of-the-art AI models, and inspire the uptake in follow-up projects.

   These initiatives allow Deltares employees to deepen and consolidate knowledge on technical implementations and keep an eye on the rapid evolution of the AI landscape. Based on preliminary results of this research we have identified several points of focus that will inspire efforts in the 2025 plan:

   - Datasets and data-driven scientific discovery: It is becoming apparent that the availability and operability of large datasets will be of paramount importance in the context of data-driven science. First experiments with informing LLMs with the Deltares knowledge repository are underway, however Deltares should keep a close observation on the technical needs and constrains to ensure operability of its information to train LLMs and hybrid emulators.
   - Foundational AI Models: Vision-text large models show impressive results on generalizing and transferring reasoning capabilities across domains. Identifying external developments of novel foundational models (for instance satellite-specific vision reasoning models) and implementing routines at Deltares is of fundamental importance. This has implications for a number of critical workflows at Deltares, including automation of expert interpretation of data-model results, rapid interaction with remotely sensed imagery, increase in the speed of training and deployment of data processing routines in the facilities and field.
   - Model emulation and hybrid models: Keeping up-to-date knowledge on emulation strategies that accommodate high-dimensional spaces (dynamic grids, time-space input dynamics) is of high importance. Data-driven PDE solver emulators (e.g. NVIDIA Modulus platform) or deepening our understanding of the use of GNNs and Physics-Informed neural networks will still be a focus point.

2. Innovations in sensing and monitoring

   Acquisition of data and innovative sensing technologies are core enablers for Deltares. Keeping an up-to-date knowledge of available sensing technologies that can be transferred to our domain is key to be a go-to-place knowledge institute nationally and keep a market position internationally. This will include scanning novel measurement equipment for laboratory / field operations and developing in-house expertise in novel measurement techniques. This may include focus points on:

   - Fostering the connection of novel measurements between hydro, soil and water quality processes.
   - Exploration of routines that facilitate and enable laboratory work, including novel wave, flow and soil dynamics measurements with Fibre-optics, LIDAR and Optical instrumentation.
   - Exploration of innovations in the field inspection techniques with the use of aerial/underwater drones

- Computational capabilities (edge computing and real-time model-physical system hybrids)
- Deltares is a world-renowned provider of processing streams for Earth Observation data in the context of infrastructure, marine and inland water systems. Further focus on strategies to leverage existing and upcoming EO sensors for our key domains and to prepare for platform-agnostic EO remote sensing pipelines will be priority points.

Part of these focus points will be addressed through an Open Call for proposals through Deltares' Ideas Platform.

The development of the program will be further supported through inspirational activities which will be partly also relate to the above-mentioned topics and serve to disseminate knowledge within the organization. These activities comprise:

- Brown Bag lectures – we will continue organizing biweekly Brown Bag Lectures in which researchers share the results of their Enabling Technology project. These lectures are well received and offer the possibility for a large audience within Deltares to take note of the experience of new and upcoming technologies
- Moonshot Hackathons – we will organize two Hackathons, preferably in cooperation with external partners, to test and protype new technologies in workflows for modeling and experimentation. Past Hackathons have been looking in to integration of cloud-computing and complex model integration for compound flood forecasting in cooperation with Moonshot 'Making the world's population safer from flooding', data fusion and visualization for geotechnology in cooperation with Moonshot 'Resilient Infrastructure' and Agentic Workflows for automated construction of model pipelines with Moonshot 'Delta's remain habitable'.
- Execute Horizon Scans and organize conferences – we will organize two technology horizon scans and present results during workshops/conferences.

7.5 Experimental Facilities

Deltares has various experimental facilities ((Hydro-geotechnical-chemical-bio facilities) and the competence to create valuable measurement set-ups and to conduct and analyze experiments. Our experimental facilities are crucial in the knowledge chain for developing evidence-based solutions to societal problems, which are addressed by the Deltares 'Moonshots.

The Experimental Facilities offer:

- validation and calibration of software and models;
- insight into physical processes that cannot yet be simulated numerically;
- opportunities to experiment with variable and extreme conditions on a smaller scale and at acceptable costs;
- verification of the design of large structures, leading to cost savings and risk reductions;
- supporting innovations in the proof-of-concept phase.

Experimental facilities include more than the physical facility itself. They also involve the people, measurement technique(s), (control) software, data acquisition and processing to FAIR data. Deltares also performs field research, in which field measurements and field experiments are carried out.

Strategic experimental facilities

Deltares has four clusters of experimental facilities. The first cluster consists of our ***wave and flow facilities***. This includes our 300-metre-long Delta Flume where we can simulate waves of more than 4.5 meters high. These facilities are essential to test the interaction between hydraulic loads and the structural and hydraulic response contributing to innovative design and (safety) assessment of infrastructure such as primary flood defences, port infrastructure (breakwaters, quay walls, navigation channels), energy infrastructure such as energy islands, wind farms, pipelines, and intake and outfall systems.

The second cluster consists of our ***Geofacilities***. This includes our GeoCentrifuge, in which we reduce physical processes in the subsurface that in reality takes years, to hours or minutes. In the geofacilities, we conduct research into issues relating to the shallow subsurface with focus on soil-structure interaction. An example is the better understanding of physical processes related to (in)stability of dikes (primary flood defences), such as macro-stability and piping or testing new concepts of a quay-wall design for a harbour that is more resilient.

The third cluster consists of our **B*io-chemical and sedimentary facilities*** for water, soil and sediment. In the Deltalab, we conduct experimental research on ecological and chemical quality of water and subsurface systems. We experiment with innovative techniques to measure and analyse the substances and micro-organisms in the soil, sediment and water system, their properties and how to influence and manage these substances and micro-organisms, to find solutions to deal with harmful substances and understand mechanisms of greenhouse gas emissions. The quality of water, soil and sediment is important for the quality of life.

Next to these three clusters there are as well, the water-soil-flume, which is a multi-purpose flume for testing the interface between water-soil and structures or equipment. The last cluster is formed by our ***Field experimental facilities*** which are mainly focused on surveying and monitoring the subsurface, for example for heat storage or assessing rail embankments. . The relationship between the experimental facilities and the Moonshots is presented in figure 7.3.

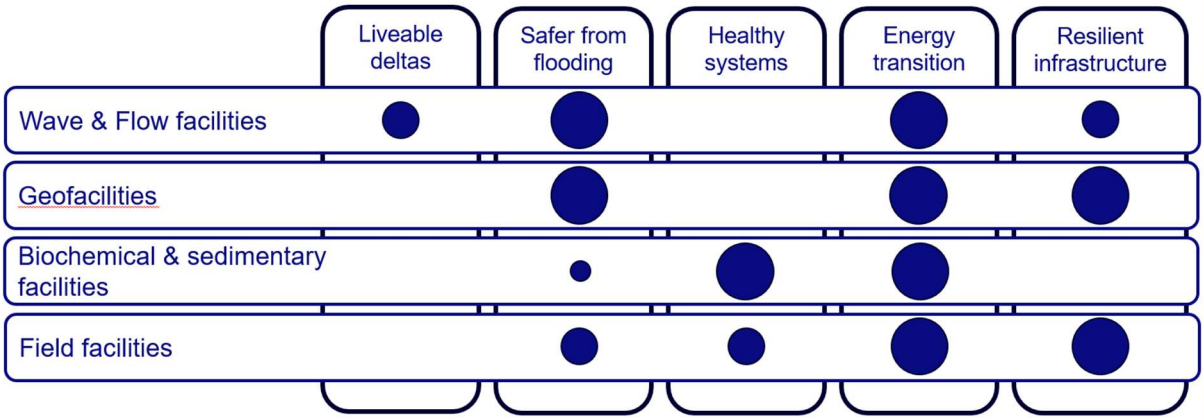

Figure 7.3 - Relationship between the experimental facilities and the Moonshots.

The activities within the experimental facilities will develop its program in more detail and will be based upon the Moonshot and demands for experimental facilities, the Future Trend Report of the Deltares Young Science Counsel, the internal mid-term review of the Deltares Science Council and Deltares experts with niche expertise on physical modelling. The main activities in 2025 are divided into five Program Lines, which are described below:

- Program Line 1: Strategic outlook on experimental facilities
- Program Line 2: Enhanced cooperation with (inter)national experimental facilities providers
- Program Line 3: Use of experimental facilities within Moonshot 'Resilient and healthy water and soil systems for humans and nature' and Moonshot 'Resilient Infrastructure'
- Program Line 4: Provision of access to experimental facilities for Dutch SME's and start-ups
- Program Line 5: Improvements in experimental techniques and procedures

Within Program Line 1, an integral strategic outlook on our experimental facilities will be carried out. This outlook will include an inventory of future required experimental research infrastructure ensuring that we are equipped with required experimental research infrastructure to address future societal challenges in the field of water and shallow subsurface as addressed in the Moonshots. Next to the future experimental infrastructure, the strategic outlook would also consider the human capital, measurements and control techniques and (control) software.

Program Line 2, supports the collaboration with renowned national and international research organisations/academic institutions on experimental research and to explore how we can optimize our experimental research by cross fertilizing our combined specialist expertise.

Within Program Line 3, impetus will be given to the use of the experimental facilities as part of the research carried out within the Moonshots. In 2025 experiments will be carried out in conjunction with Moonshot 'Resilient and healthy water and soil systems for humans and nature' and Moonshot 'Resilient Infrastructure' . This Program Line specifically supports the objective of the Experimental Facilities in generating evidence-based solutions.

Program Line 4 strives to support innovative initiatives from Dutch start-ups and SME's by offering free access time to our experimental facilities. With the SME challenge, Deltares is

offering access to the Hydro and Geo experimental facilities for a proof-of-concept of their innovations. By this, we aim at feasibility studies or improvements in early stage of development (i.e. low TRL).

Within Program Line 5, we aim to further improve the quality of our experimental facilities by identifying, further developing and implementing innovations, protocols, techniques or software leading to higher impact of our research output. Furthermore, implementing innovative or upgraded research infrastructure and protocols lead to a more efficient way of conducting experimental research, making the experimental facilities more accessible to our stakeholders. This also includes implementation of new measuring and monitoring technology which have the capability to enhance the quality of our experiments or can contribute greatly in measure and monitor relevant state parameters of constructions or the natural environment.

The above-described activities contribute to the statutory obligation of Deltares to maintain, further develop and provide access to its experimental facilities. The SITO-IS activities in 2025 contribute to this by elevating the performance of the experimental facilities leading to higher impact of our experimental results and better accessibility to the facilities for our employees and stakeholders. This is while providing and maintaining a strong connection with our SITO-IS research in the Moonshots as part of our mission-driven strategic agenda.

7.6 Networks and university positions

7.6.1 Alliances with universities

To achieve the strategic goals and ambitions of Deltares Moonshots, active alliances with universities and institutes of higher education are essential. These close relationships are realized, 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 (strategic) chairs and appointments, while maintaining ongoing relations and collaborations.

Through this program, we support 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 water and subsurface. 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 (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. This through, 13 professors, 10 associate professors, lecturers and researchers.

7.6.2 Networks

To maintain the knowledge base and to exchange/disseminate knowledge, the Deltares knowledge facilities finance networks with research institutes, the private sector, and scientific networks. These networks have a cross-programme coverage and are of strategic importance in facilitating the development of mission-driven work. The networks operate on a national, European or global scale. At the national level, these are networks in areas such as river research (NCR), coastal research (NCK), flood risk management (ENW), underground construction (COB), offshore energy (GROW) and digital innovation in the water sector (Digishape). EcoShape – Building with Nature is a network of organizations and individuals, working together to advance the application of Building with Nature in water related societal issues.

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, subsurface, climate, 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.

At the global level, network activities are supported in the field of climate (IPCC), hydraulic engineering (PIANC), meteorology (WMO), nature-based solutions in water management (Ecohydraulics) and the Collaborative Modelling community of practice.

Deltares

8 Financial framework

This 2025 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 € 23.476.000 for the 2025 financial year.

The 2025 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 2025 Activity Plan will be submitted to the Ministry of Economic Affairs and Climate (EZK) in December 2024 together with an auditor's report.

8.1 Commitment to mission-driven working

In 2025, approximately two-thirds of the institute subsidy (approx. € 12,7 million) will be used directly for activities that contribute to the national missions and international agendas as described in the KIAs. Approximately € 9,9 million of the total institute subsidy will be used for activities relating to the knowledge facilities.

The first table shows the indicative budget allocation per moonshot, for the Knowledge Facilities and for the Programme Management.

Table 8.1 - Budget distribution SITO-IS 2025.

	Indicative budget Euros x 1,000
Moonshot Liveable deltas in a changing world	3,078
Moonshot Making the world safer from flooding	2,479.5
Moonshot Resilient and healthy water and subsurface systems for humans and nature	3,078
Moonshot Energy transition & Climate Neutrality	1,795.5
Moonshot Resilient infrastructure	2,308.5
Sub-total Moonshots	**12,739.5**
Knowledge facilities:	
- **Enabling Technologies**	950
- **Software and PMT**	4,150
- **Data & data science (digital transformation)**	950
- **Experimental Facilities**	1,600
- **University Positions**	1,250
- **Knowledge Networks**	350
- **Emerging topics**	332.5
- **SME**	300
Sub-total Knowledge facilities	**9,882.5**
Programme Management	854
Total in euros x 1,000	**23,476**

The next 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).

Table 8.2 - Budgets located to the KIAs

	KIA C&E	KIA CE	KIA AWF	KIA H&C	KIA Enabling technology	Total contribution of KIAs
Moonshot Liveable deltas in a changing world			**			
Moonshot Making the world safer from flooding			**			
Moonshot Resilient and healthy water and subsurface systems for humans and nature			**			
Moonshot Energy transition & Climate Neutrality	**		**			
Moonshot Resilient infrastructure	*		**			
Enabling Technologies/ Digital Transformation			**		**	
Total in euros x 1,000	**1,500**	**0**	**10,000**	**0**	**1,250**	**12,750**

8.2 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 national and international co-financed research projects amounting to approximately € 7 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 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.

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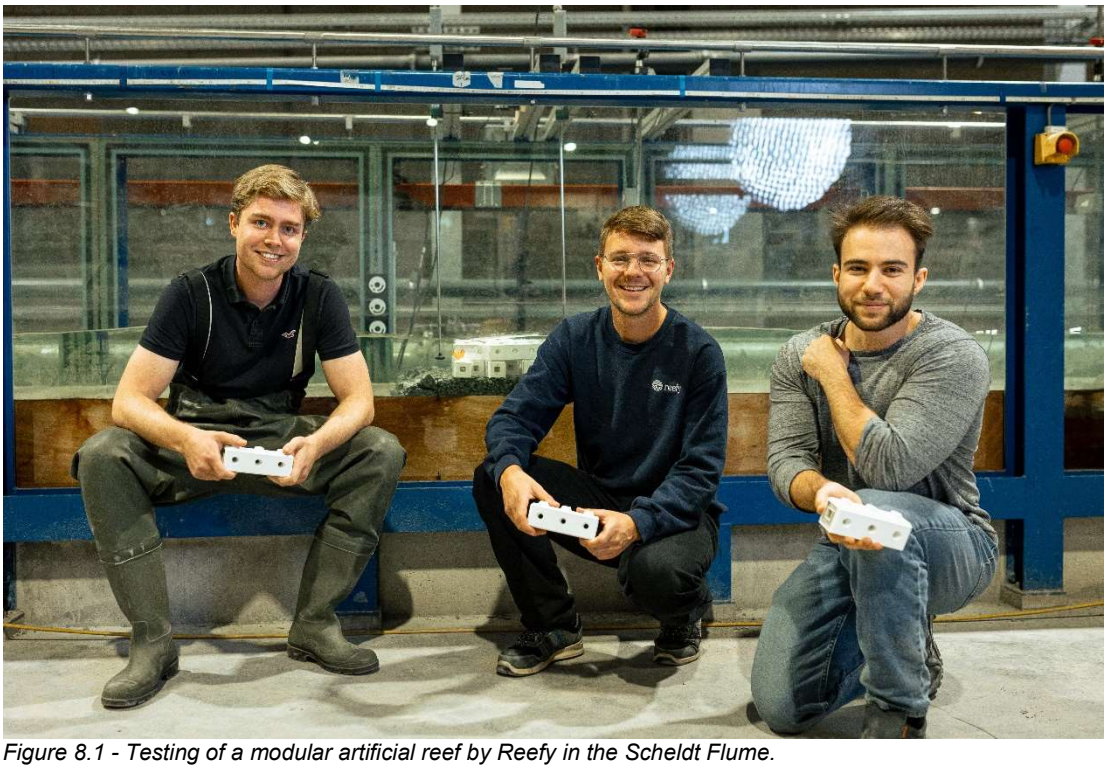

Figure 8.1 - Testing of a modular artificial reef by Reefy in the Scheldt Flume.

Appendix A: Software and Moonshots

		Liveable deltas in a changing world	Making the world safer from flooding	Resilient & healthy water and subsurface systems	Energy transition & Climate Neutrality	Resilient Infrastructure
Geo Software	Product					
	KRATOS		X		X	X
	D-GEO Suite - Embankment: D-Stability D-Settlement D-Geo Flow	X	X			X
	Pre-decessors (D-Series): D-Foundations D-Geo Pipeline D-Settlement D-Sheet Piling		X		X	X
	RA2CE	X	X			X
	BOI		X			
	MPM		X		X	X
Hydrology	iMOD Suite/MODFLOW	X		X		X
	RIBASIM			X		X
	Wflow	X	X	X		X
	HydroMT	X	X	X		
	Delft-FIAT	X	X			X
	Climate stressTest Toolbox			X		
	CRC Tool	X		X		
	RTC-Tools				X	X
	FloodAdapt		X			
Hydrodynamics & Morphology	Delft3D FM & pre-decessors (SOBEK, Delft3D 4 etc.): D-Flow FM D-Real Time Control D-Morphology D-Waves (SWAN)	X	X	X	X	X
	SFINCS	X	X			X
	XBeach		X			X
	WANDA Suite (Heat, Control, Liquid)				X	X
	WarmingUP Design Toolkit				X	
	CFD				X	X
	SWAN		X		X	X
	ORCA				X	
	PHAROS					X
	ShorelineS	X				X
Water Operations (FEWS)	Delft-FEWS		X	X	X	
	Open Archive		X			
	Web Operator Client		X			

	OpenDA		X			
Water Quality & Ecology	DELWAQ scientific toolbox			X	X	
	Delft3D FM & pre-decessors (SOBEK, Delft3D 4 etc.): D-Water Quality	X		X	X	
	D-Eco Impact (HABITAT)	X	X	X	X	X
	D-Emissions			X	X	
	Tools for co-creation (DSS, Digital Twins, Digital Services)	X	X	X	X	X

Appendix B: KIA, missions and MMIPs

KIA	Mission	MMIP	Description
KIA CE (Climate & Energy)	A		**A completely CO2-free electricity system in 2050**
		A1	Renewable electricity at sea
		A2	Renewable electricity generation on land and in the built environment
	B		**A CO2-free built environment in 2050**
		B3	Acceleration of energy renovations in the built environment
		B4	Heat and cold
		B5	Electrification of the energy system in the built environment
	B+		**Future-proof built environment in 2050**
			Circular construction and infrastructure
			Extending the lifespan of the built environment
			Climate-adaptive, nature-inclusive and environmentally aware construction
	C		**A climate-neutral and circular industry in 2050**
		C6	Raw materials and products for carbon circularity
		C7	CO2-free industrial energy management
		C8	Chain and system aspects
	D+	D+9	**Emission-free mobility for people and goods in 2050**
	E	10/11/12	**Net climate-neutral system of agriculture and nature**
		13	A robust, socially supported energy system
KIA CE (Circular Economy)		1	Design for circularity
		2	Circular raw material chains and processes
		3	System transition and acceptance
KIA AWF (Agriculture, Water and Food supply)	1		**Resilient nature**
		1A	Strengthen nature and biodiversity
		1B	Strengthen and appreciate ecosystem services
		1C	Effective and sustainable use of nature based solutions
		1D	Transition to one nature-inclusive society
		1E	Technology and data driven nature policy and management
KIA AWF	2		**Sustainable agriculture and horticulture**
		2A	Land and horticulture indoors boundaries of natural habitat
		2B	Earn assets, perspective & value creation
		2C	Resilient vegetable production on one vital soil/substrate
		2D	Resilient lifestock farming systems
		2E	Circularity, production & usage sustainable raw materials
		2F	Energy transition in the country and horticulture
KIA AWF	3		**Vital rural area in a climate-proof Netherlands**
		3A	Future-proof spatial planning of rural areas
		3B	Future-proof design of built-up areas
		3C	Toekomstbestendig zoetwatersysteem

	4		**Sustainable and valued food that is healthy, accessible and safe**
		4A	An ecologically and economically sustainable agriculture & food system
		4B	Sustainable processing and food safety, fresh and processed
		4C	Alternative proteins: chain, products and consumers
		4D	Sustainable and healthy food supply and consumer behavior
		4E	Food security now and in the future (global/EU/NL)
		4F	Multiple valorization of food and non-food
	5		**Sustainable and safe use of the North Sea and other larger waters**
		5A	Sustainable North Sea and oceans
		5B	Sustainable rivers, lakes and intertidal areas
		5C	Nature-inclusive agriculture, fisheries and water management in the Caribbean Netherlands
		5D	Sustainable blue economy
		5E	Aquatic food production
	6		**Safe and resilient delta**
		6A	Sustainable measures for safe, resilient, navigable deltas
		6B	Reducing (construction) raw materials and circular dredging, sand and gravel use
		6C	Safe, circular and climate-neutral shipping
KIA H&C (Health & Care)	1		Lifestyle and living environment
	2		Care in the living environment
	3		Participate and matter with an illness or disability
	4		Quality for people with dementia
	5		Better protection against health threats
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
	12		Responsible consumption and production
	13		Climate Action
	14		Life below Water
	15		Life on Land
	16		Peace, justice, and strong institutions
	17		Partnerships for the goals
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

Appendix C: 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 BeschermingsProgramma	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
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
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
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