R&D Highlights 2013
One of the Deltares aims is to make R&D results more accessible to the public and the private sector. Many roads lead to Rome, and there are numerous ways of disseminating this knowledge: scientific publications, technical publications, reports, the Deltares website, wikis, communities of practice, courses and software. This R&D Highlights report for 2013 presents a selection of the R&D conducted in 2013. It is structured along the lines of the societal issues that are central to the Deltares mission. To enhance interactivity, one or more contacts are listed for each project and readers interested in more details should approach them. A pdf version of these R&D Highlights 2013 can be downloaded from www.deltares.nl. The separate papers can be found digitally at kennisonline.deltares.nl. Re-use of the knowledge and information in this publication is encouraged, on the understanding that due credit is given to the source. However, neither the publisher nor the authors can be held responsible for any consequences resulting from such use.
Dear reader,
It is my pleasure and honour to present the Deltares research highlights for 2013. More than 850 Deltares employees are involved in high-grade research and consultancy in the field of delta technology. This is the technology needed for sustainable living, work and recreation in low-lying, densely populated areas at the interface of land and sea: enabling delta life. This requires technical skills, as well as a thorough knowledge of the functioning of the natural system and its response to human activities and environmental change. It also requires a broad interdisciplinary view of the functions and how they can be integrated to the benefit of society, now and in the future. All of our activities, whether applied research or specialised consultancy, are intended to contribute to this body of knowledge. I hope this report shows that Deltares and its partners have made significant progress in adding to this treasury of interdisciplinary knowledge.

I am proud to present this collection of highlights, which were produced in both subsidised research programmes and commissioned contract work. If a project description stirs your interest, please don’t hesitate to get in touch.

Professor Dr Jaap Kwadijk
Deltares Science Director
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Introduction

Deltares is the Dutch applied research institute in the field of delta-technology. Its mission is to develop and apply top-level expertise in the area of water, subsurface and infrastructure for people, planet and prosperity.

Deltares works closely with governments, businesses and research institutes in the Netherlands and abroad. In doing so, it generates societal, economic and scientific impact nationally and internationally. These are the core values Deltares wants to be judged on.

Deltares aims to join the world’s top in its field by continuing to expand and consolidate its knowledge base. Deltares is an applied research institute and so its success depends on the extent to which its knowledge is applied successfully in and for society. The guiding principle for the choices Deltares makes within its research projects and in the market place are the practically oriented research objectives. Programmes and projects are selected on the basis of their potential contribution to the knowledge objectives. Through thematic portfolio management, Deltares makes coherent and optimal use of its different funding sources and partners.

Since the start in 2008, Deltares has organised its Strategic R&D along the lines of five prominent societal themes: Flood Risk, Ecosystems and Environmental Quality, Water and Subsoil Resources, Delta Infrastructure and Sustainable Delta Planning. Meeting demands from society is the key to long-term continuity of institutes like Deltares. However, the impacts on society of the funding of delta research have to be made clear and private
companies – including small and medium-sized enterprises (SME) – must benefit from the results of government-funded research. As innovation is believed to reside mainly in the private sector, stimulation measures have been implemented for this sector in order to boost innovation. One of those measures is the broadening of research alongside specialisation, and a focus on how to ensure that knowledge is embedded more effectively in practice.

Recently the Dutch government has defined nine so-called ‘top sectors’ as a structure to support, together with businesses and scientists, the different economic sectors (e.g. agro-food, energy, logistics and more) in their ambition to maintain or achieve a leading position in the world. For Deltares the top sector ‘Water’ with the cluster ‘Delta Technology’ is the most relevant. One of the spearheads is “Enabling Delta Life”: the core business of Deltares.

Since 2008, the Strategic R&D was organised in the five societal themes mentioned above. However, all Deltares activities are knowledge-intensive and, in principle, contribute to the knowledge portfolio. To direct all these activities, Deltares has developed the Knowledge Strategy 2013-2016 “The World of Deltares”, moving the Deltares Strategic Plan 2012-2015 further forward.
Mind maps at the level of total R&D, at theme level and at programme level.
The World of Deltares 2013-2016
Deltares aligns its knowledge portfolio in five key themes. These are:
- Flood risk
- Ecosystems and Environmental Quality
- Water and Subsoil Resources
- Delta Infrastructure
- Sustainable Delta Planning

It may be emphasised once more that these themes involve more than the subsidised Strategic Research funding. In each theme, Deltares engages in different types of activities: strategic research, applied research, product development, knowledge transfer and consultancy. All these activities are knowledge-driven and innovative. Together, they contribute to the Deltares thematic knowledge portfolio. A good mix of knowledge, expertise, products and services in the portfolio is essential. Further development of this portfolio guides the Deltares decisions about both the research programmes and the market activities. The selection of programmes and projects is governed by their possible contribution to the knowledge goals. Balanced thematic portfolio management leads to a coherent input from the different sources (financial and otherwise).

Fundamental research generally takes place at universities. Deltares engages in basic research itself only when necessary, preferably in collaboration with a university or an academic research institute. Deltares staff working on doctorates and university-employed PhD-students hosted by Deltares are important here. In most cases, however, the role of Deltares is to link academia with practice. Deltares engages with others in the
strategic and applied research phases that follow fundamental research. The same holds for the development of software and models. Once these products have been shown to work in practice, market parties will gradually take over. To smoothen the transition, these parties are invited to participate in the later stages of development.

The themes have been subdivided into about 30 programmes. The financial input mix evolves through the lifetime of a programme: initially strategic research subsidy and co-funding from European and national research funds will dominate, but in the course of time applied research funds and market contributions will become more prominent. It is, however, the ambition of Deltares to enhance market commitment in all phases of a development. In this way, knowledge valorisation will receive more attention from the outset of the development process.

Subsidised research programmes tend to be “eternal” (~10 years or more). To counteract these long periods, 20 - 25% of the strategic research programmes is terminated every year (resulting in an average duration of 4 - 5 years), so as to create distinct decision points (“continue or not?”) and therefore create the space required for new lines of development. To prepare for these lines, a number of “scouting” projects are initiated every year alongside the ongoing programmes within a theme.
Disciplines

The basis of the activities of Deltares lies in disciplinary knowledge in a number of fields. About 20 disciplines have been defined. They are grouped in clusters, each moderated by one of the Theme Managers and a member of the Science Council.

Together, the clusters form a framework of disciplinary knowledge. The four “pillars” in the building represent the technological core disciplines of Deltares. Moreover, Deltares wants to be an authority in the application of this knowledge in “engineering” – this is represented by the horizontal beams – together with, and for the benefit of, public and private parties. The System Informatics cluster (including scientific computing, probabilistic analyses and observational methods) provides knowledge and expertise as support for the other discipline clusters. The discipline cluster Social Sciences and Policy Analysis (SSPA) makes the connection with the world of governance and policy processes. In the latter two clusters, Deltares aims to stand out in integrating and connecting other disciplines, rather than in the disciplines themselves.
Advisory Council
To advise the management about research and strategic positioning, Deltares has an external Advisory Council with representatives from the knowledge world and from the commercial sector. The issues dealt with by the Council are of a long-term nature, such as the question where Deltares should invest to realise its ambitions, and of which research issues should be addressed to produce timely answers for problems to be expected in the future.

The members of the Advisory Council are:
- **Professor Jacob Fokkema** (chair), Delft University of Technology
- **Piet Besselink MSc**, DHV Holding BV
- **Professor Rietje van Dam-Mieras**, Leiden University
- **Professor Aad van der Horst**, Delta Marine Consultants
- **Professor Ronald van Kempen**, Utrecht University
- **Cees Slingerland MSc**, Environmental Sciences Group, Wageningen University and Research Centre
- **Professor Marcel Stive**, Delft University of Technology

Science Council
The Deltares Scientific Council consists of a number of Deltares members of staff with international reputations - mostly part-time university professors - who monitor the quality of the knowledge activities at Deltares and provide the management with advice, solicited or unsolicited, about the research programme, strategic investments, the disciplines and the relationships with the universities.
In 2012 Deltares established the Young Scientific Council. The Young Scientific Council will give solicited or unsolicited advice to the Scientific Council about the Deltares knowledge development, especially in the long-term. The Scientific Council advanced the idea for a Young Scientific Council in order to import the knowledge and networks of these young professionals and so stay informed of the latest scientific developments, thus guaranteeing the high-level knowledge of Deltares. Moreover the Scientific Council hopes to promote mutual collaboration and interdisciplinary research by this new council.

The members of the Scientific Council are:
- Professor Eelco van Beek
- Professor Marc Bierkens
- Dr Frans Klijn
- Professor Jaap Kwadijk (chair)
- Professor Remi Laane
- Professor Huub Rijnaarts
- Professor Dano Roelvink
- Professor Frits van Tol
- Dr Rob Uittenbogaard

The members of the Young Scientific Council are:
- Dr Karin de Bruijn
- Dr Gilles Erkens
- Dr Marjolijn Haasnoot
- Dr Mandy Korff (chair)
- Dr Ivo Pothof
- Dr Bregje van Wesenbeeck
- Dr Hessel Winsemius
Facts and figures

The annual turnover of Deltares is about 110 M€, half of which is generated by R&D. This turnover is generated by about 850 employees, 550 of which in scientific positions.

Deltares is also a breeding ground for MSc and doctorate students. Some are Deltares employees, others are co-supervised and supported (some financially) by Deltares. About 75 doctorate students are co-supervised by Deltares staff and, every year, 5 - 10 colleagues obtain their doctorates. About 15% of the Strategic Research subsidy is allocated to doctorate studies.

Fourteen doctorates supported by Deltares were completed in 2013, nine of them being Deltares employees:

- **Alex Rohe** (TU Delft) Towards parameter limits of displacement boundary value problems for Mohr-Coulomb models
- **Kees den Heijer** (TU Delft) The role of bathymetry, wave obliquity and coastal curvature in dune erosion prediction
- **Fedor Baart** (TU Delft) Confidence in coastal forecasts
- **Marjolijn Haasnoot** (Univ Twente) Anticipating change: sustainable water policy pathways for an uncertain future
- **Mandy Korff** (Univ of Cambridge (UK)) Response of piled buildings to the construction of deep excavations
- **Willem Toonen** (Univ Utrecht) A Holocene flood record of the Lower Rhine
- **Willem Ottevanger** (TU Delft) Modelling and parameterizing the hydro- and morphodynamics of curved open channels
- **Perry de Louw** (VU Univ Amsterdam) Saline seepage in deltaic areas
- **Thorsten Balke** (Radboud Univ Nijmegen) Establishment of biogeomorphic ecosystems. A study on mangrove and salt marsh pioneer vegetation
The Deltares staff include 14 part-time university professors. Other staff are involved on a part-time basis as assistant or associate professors, or as senior researchers. Deltares values these links highly, not only to help define and supervise research and disseminate knowledge, but also for recruitment of young talents. Deltares’ academics are alumni from a variety of universities, including universities abroad. About 10% of the Deltares’ academic staff are from countries outside the Netherlands.

In 2013 Jaap Kwadijk was appointed Professor modelling water management and climate at University of Twente.

Deltares works with universities to invest in knowledge centres at the universities of Delft, Utrecht, Twente and Wageningen. Current examples are the Geo-Engineering Knowledge Centre at Delft University of Technology, the Risk Management Knowledge Centre in conjunction with the University of Twente, and UCAD, the Utrecht Sustainable Earth Research Centre, a collaboration involving Utrecht University, TNO, Deltares, KNMI, KWR, PBL and RIVM.
Flood Risk

scope
The low altitude of the Netherlands means that protection against flooding is a permanent concern. Soil subsidence and climate change are exacerbating the problem. In addition, we are making more and more demands on the spatial quality of the country. Smart dikes, improvements in our understanding of the real strength of, and loads on, the dikes, the relaxation of restrictions on water flows, warning systems and non-technical alternatives in the eventuality that things go wrong after all: these things make up the impact of Deltares.

background
Protection against floods is the day-to-day, ongoing and primary concern of us all. The issue, too, is how to maintain safety in this area in the long term, particularly taking into account increasing socio-economic pressure on the available space and the capital invested in this country. Water safety and spatial quality in our country require answers at a range of temporal and spatial scales.

In the past, water safety policies in the Netherlands have been based primarily on the construction of water defences: structures to limit the risk of flooding, even at extremely high water levels. This approach makes it essential to assess the quality of the defence structures and to understand the associated failure mechanisms in dikes. It is characterised by the restricted spatial and time scales.

More and more, attention is focusing on the combination of both flooding probability and secondary damage: the flood risk.
So water safety cannot be dissociated from spatial and socio-economic developments in the hinterland. Requirements in the area of water defences, water management, the economy, transport, nature, recreation and housing demand a coherent, integrated approach. This amounts to a more large-scale approach in both space and time.

The ongoing increase in the flow of data does not make decision-making easier, especially when a calamity is imminent. Further development of the general tools and techniques used in operational flood forecasting systems for rivers and coastal systems is needed to improve the quality of the forecasts. Improvements in the quality of flood forecasting should lead to better risk analysis (e.g. dike strength) and improved adaptation times in relation to protection strategies and emergency measures.

In the coastal zone, sand is the vital functional element. The current coastal management policy uses replenishment to keep the amount of sand in the coastal area up to standard, maintaining or even enhancing safety in a natural way, and responding to the consequences of rising sea levels sustainably and flexibly.

Six programmes constitute this theme: Flood risk strategies, Rapid assessment tools, Real time information for flood event management, Coastal, estuarine and river morphodynamics, Event-driven hydro- and morphodynamics and Dikes, levees and dams.
The EU Critical Infrastructure Preparedness and Resilience Research Network (CIPRNet) is establishing a Network of Excellence in Critical Infrastructure Protection R&D for its stakeholders. The network will provide long-lasting support from the CIP research community for end users, enhancing their preparedness for CI-related emergencies, and provide other stakeholders with knowledge and technology to improve the understanding and mitigation of the consequences of CI disruption and to enhance CI resilience.

2013 saw the launch of two of the main products in which Deltares is involved. In the first place, CIPRNet designs and builds a Decision Support System for crisis organisations. This DSS is expected to establish a picture of how the direct impacts of natural hazards cause indirect effects via a cascade passing through different critical infrastructure networks, and to show which measures could be taken to reduce damage. Natural hazards can occur anywhere and differ considerably in nature (flooding, landslides, earthquakes, droughts, ...). The DSS therefore needs to be flexible and to be able to use different data sources and types to produce valuable products quickly. Techniques combining different models will be used to make this possible.

Secondly, two different scenarios are being developed as test cases for this DSS: one earthquake scenario in Italy and one cross-boundary flood scenario in Germany and the Netherlands. Deltares is involved in the second scenario. So far, the emphasis has mainly been on gathering information and data about the
specific floods and the different critical infrastructure networks. The scenario, which will be finalised in the first half of 2014, consists of a high water event that leads to a number of catastrophes along the river: dike breaches cause flooding and the fall-out of a power station, high groundwater levels cause a tunnel to lift and erosion near a bridge raises issues about evacuation. Deltares is working with German and French partners on this scenario. Workshops are being organised to pool the efforts of the partners and to determine how different approaches to the problem benefit from each other.

Staff exchanges are being used as a way of learning from each other. Specific issues to be addressed relating to the DSS are how the future stakeholders will use it and how the different databases and models from the different partners can be combined into a single DSS.

An understanding of cascading effects and the design of an integral approach to this problem will be a stepping stone for further research and projects looking at cascading effects.
Gravel beaches and barriers occur on many high-latitude, wave-dominated coasts across the world. Due to their natural ability to dissipate large amounts of wave energy, gravel coasts are widely regarded as an effective and sustainable form of coastal defence. However, during extreme events waves may overtop, overwash, and even lower, the crest of the gravel beach, flooding the hinterland. Despite the obvious societal importance of gravel beaches and barriers, only limited guidance is currently available to provide beach managers with operational management tools to predict the response of gravel beaches to storms. To address this shortfall, Deltares is working in partnership with lead partner Plymouth University, the Channel Coastal Observatory, the Environment Agency, HR Wallingford and UNESCO-IHE to improve our understanding of storm impacts on gravel coasts and to develop a predictive modelling capability for storm impact on these coasts.

A major reason for the lack of knowledge of storm impact processes on gravel beaches is that, by comparison with sandy beaches, physical data about gravel beaches during storms are relatively scarce. This is generally attributed to the logistical difficulties of conducting measurements on a highly energetic and dynamic beach face. The first objective of this research project was to significantly boost the amount of storm impact field data about gravel beaches by using remote-sensing techniques (cameras, LiDAR) and robust in-situ instruments to make detailed measurements of swash hydro- and morphodynamics during storms on six gravel beaches along the coast of the UK.

The field data collected during this project are being used to develop and validate the XBeach model for application on gravel
beaches. The XBeach storm impact model, which was originally developed for sandy coasts, has been extended to include groundwater interaction and phase-resolved short wave motions on gravel beaches, and is currently being developed to simulate gravel sediment transport and morphodynamic response. Validation results show that the XBeach model already accurately predicts storm hydrodynamics on gravel beaches, including critical runup levels and wave overtopping. The results of this model show a marked improvement over current empirical model predictions.

In order to ensure the transfer of the knowledge developed in this project to coastal managers, the project is aiming to produce simple end-user tools. One of these tools, a simple graphical user interface (GUI) for the newly developed XBeach model for gravel coasts, is currently under development. This tool will be used alongside improved wave runup and overtopping relations to help coastal managers assess plans to reduce the risk of coastal disasters.

Further reading
http://www.research.plymouth.ac.uk/coastal-processes/projects/nupsigsite/home.html
A question that is high on the agenda in river engineering in the Netherlands and Germany is: “How much flow resistance and backwater is generated by submerged river training structures (such as groynes) and how can we accurately represent these effects in our numerical models?” Many numerical river models now in use have a relatively coarse grid resolution of around 20-40m. All topographical features smaller than this scale are “subgrid” and require special treatment to include their effects in the models. For this reason, groynes and dikes have commonly been modelled as subgrid structures that modify the flow by adding a local energy loss to the flow equations. The aim of this work is to investigate the validity of this approach.

Several new approaches have been developed that enable the efficient application of high-resolution models, allowing us to compare coarse and fine resolution models. One of these approaches is the subgrid method, which integrates high-resolution topographic and land-use data in coarse-grid models, providing a much more accurate representation of the flow resistance over variable topography. This approach considerably increases the accuracy of coarse-grid models, which we can run very rapidly.
A second approach is based on the application of hierarchical grids, with which we can efficiently handle the different scales of the problem on a sequence of grids. When numerically modelling a river on a very high-resolution grid, a large part of the solution time is taken up by the initial phase, in which the upstream and downstream boundary conditions need to ‘match’ and the water is distributed over the domain. This initial phase can be realised very efficiently on a coarser grid, especially when applying the subgrid method mentioned here, to make sure the topographic and land-use data of the original high-resolution model is included. Using this combined approach, we can simulate high-resolution river models efficiently. Depending on the model resolution and complexity we can run the simulations 10-120 times faster. For example, we can now simulate a 17 km stretch of the Elbe River in Germany, achieving a quasi-steady state in 3 hours on a grid with 2.7 million cells (grid resolution 2x2m), using a sequence of 6 grids. By comparison, the same exercise using the finest grid takes 3 days. In other words, the new model runs 24 times faster.

With the efficient model approach as described above, we are able to study the detailed flow over and around groynes and the flow resistance these groynes cause. We can compare with simpler and coarser models to see how they compare with the high-resolution results.
The aim of the four-year European FP7 project FloodProBE (Flood protection for the Built Environment) is to learn more about flood resilience and flood protection performance in order to balance investments in flood risk management in urban areas. To this end, technologies, methods and tools for assessment purposes and for the adaptation of new and existing buildings and critical infrastructures are being developed, tested and disseminated.

Three priority areas are addressed:
1) the vulnerability of critical infrastructure and the assets with a high value density, including direct and indirect damage;
2) the assessment and reliability of urban flood defences, including the use of geophysical methods and remote sensing techniques;
3) the concepts and technologies for upgrading weak links in flood defences as well as construction technologies for flood-proofing buildings and infrastructure networks to increase the flood resilience of the urban system.

This paper focuses on the aspects of dike strength. Most dikes are old structures that were built several centuries ago and subsequently rebuilt or repaired (after a breach), modified and raised several times, with materials that do not necessarily match the original design of the structure. Dike foundations are naturally heterogeneous and, in general, have not been properly treated to improve their water-tightness or strength properties. Other factors such as animal activity or root growth can weaken dikes. In the urban context, there are many additional elements in dikes, such as embedded networks, pipes, or structures like houses, gardens or walls. Urban flood defences...
Flood risk comprise both soft soil embankments and hard structures. Failures are often caused by internal and/or external erosion processes, particularly at transitions between materials or between defence types. Complex combinations of defence types are typical in urban areas.

The FloodProBE project has produced a better understanding of erosion processes and clear guidance for the assessment of internal erosion (piping), surface erosion (grass cover) and erosion around transitions. Experiments have demonstrated that the prevention of backward erosion in flood defences by BioGrout is feasible without any significant reduction in the permeability of the sand.

An overview was created of new, rapid and cost-effective methods to deal with long sections of heterogeneous dikes and subsoils: geophysics and remote sensing. Tools were developed to improve the assessment of long dike sections at the scale of the dike system by combining multiple sources and different types of available information, and the use of GIS to combine these data sources at these different scale levels for a full assessment of the dike system.

Further reading
www.floodprobe.eu

Bank failure Romania
Deltares has introduced the concept of Delft3D FM Pilot Cases to make advances in software testing and validation. In a pilot case of this kind, an external client converts an existing Delft3D or MIKE model into a Delft3D Flexible Mesh model. Alongside this one-to-one model conversion, a new unstructured grid is constructed that includes all the advantages of a flexible mesh. The model results are compared for the various models and with field measurements in terms of both accuracy and performance. The client receives assistance with the modelling from one of the six Delft3D Flexible Mesh ambassadors.

The Pilot Case initiative appears to benefit both Deltares and the clients. It allows external clients to acquire early experience with Delft3D Flexible Mesh. This provides Deltares with information about typical problems that users encounter, helps to identify bugs in the software and shows how the software can be further improved; software development is pushed and steered by market demand. Furthermore, a valuable picture is established of software performance and accuracy.

The main subject of the first batch of pilot cases was two-dimensional hydrodynamic modelling. Six early adopters looking at a range of topics in different areas across the world participated in this batch:

- Coastal Science Ltd, England; Assessment of tidal energy in the Northern Channel.
- US Naval Research Laboratory US; Modeling hurricanes in the Gulf of Mexico.

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• Flanders Hydraulics Research, Belgium; Modelling of the Zandvliet – Berendrecht lock complex.
• Royal HaskoningDHV, Netherlands; Estuary modelling in Senegal.
• Griffith University, Australia; Storm surge from tropical cyclones.

The model results for the first batch were presented in November 2013 at the Next Generation Hydro Software conference at the Delft Software Days 2013. Overall, both the converted Delft3D and MIKE models produced results that were comparable with the original models. The pilot users found that converting, setting up and running the Flexible Mesh models was fast and easy. The Delft3D Flexible Mesh approach allows for an efficient model setup in which the application of high-resolution grid cells can be limited to the area of interest, minimising the number of computational cells and therefore reducing model run times. Furthermore, it makes a more flexible model setup possible in which complex geometries can be captured more easily and accurately in a triangular grid.

Further reading
San Francisco Bay is one of the largest estuaries on the U.S. West Coast. The inlet throat, a 100-metre-deep bedrock inlet, connects the bay to the Pacific Ocean. The San Francisco Bay coastal system is a complex marine system with powerful waves and tidal currents, intricate estuarine circulation and sediment transport patterns, and significant anthropogenic influences. These influences are especially noticeable in the bay and they include a mining legacy, channel dredging, aggregate mining, reservoirs, freshwater diversion, watershed modifications, urban run-off, ship traffic, exotic species introductions, land reclamation, and wetland restoration. Deltares aided the United States Geological Survey (USGS) by providing the scientific knowledge and numerical models (Delft3D modelling suite) necessary to investigate the sediment transport processes in the San Francisco Bay coastal system.

A coupled wave, flow and sediment transport model is used to quantify the sediment linkages between San Francisco Bay, the Golden Gate, and the adjacent open coast. Flow and sediment transport processes are investigated using an ensemble average of 24 climatologically derived wave cases and a 24.8 h representative tidal cycle. The model simulations show that, within the inlet, flow and sediment transport is tidally dominated and driven by asymmetry of the ebb and flood tides. Peak ebb velocities exceed the peak flood velocities in the narrow Golden Gate channel as a result of flow convergence and acceleration. Persistent flow...
and sediment gyres at the headland tips are formed that limit sediment transfer from the ebb-tidal delta to the inlet and into the bay.

A focus of the research has been on San Francisco’s main beach, Ocean Beach, that includes a persistent erosional section. This hotspot erosion threatens valuable public infrastructure as well as the safe recreational use of the beach. The Delft3D model results show that wave focusing by the ebb-tidal delta leads to strong patterns of sediment convergence and divergence along the adjacent Ocean Beach. Comparison of simulations using recent (2005) and historic (1956) ebb-tidal delta bathymetry data sets indicates that, along the north/south trending Ocean Beach, the contraction and deflation of the ebb-tidal delta have resulted in significant differences in the flow and sediment dynamics. Between 1956 and 2005 the transverse bar (the shallow attachment point of the ebb-tidal delta to the shoreline) migrated northward ~1 km toward the inlet while a persistent alongshore flow and transport divergence point migrated south by ~500 m such that these features now overlap in a way that is consistent with the observed erosion of the shoreline in this area.

**Further reading**

In the Netherlands, coastal dunes and beaches form a major part of the first line of defence against flooding by the sea. Good coastal management and maintenance of these beaches and dunes is therefore of prime importance to protect the hinterland. Since 1990, more than 200 million m³ of sand have been brought to the coast in nourishment operations. In much of the central part of the Dutch coast, the structural trend of shoreline retreat has been reversed, resulting in the advance of the coastline, and the dunes have also gained a substantial volume of sand. Along the central coast, shoreface nourishment involving volumes typically in the order of one to several million cubic metres are applied in 3- to 5-year intervals. The available data set for coastal development since 1965 facilitates the study of the cumulative effect of sand nourishment at both the decadal and regional scales.

Nourishment has proved effective in maintaining the coastal sediment volume at erosion hotspots, for instance near the villages of Bergen and Egmond. They have stopped structural erosion and increased the coastal volume, resulting in the progradation of the upper shoreface, beach and frontal dunes. However, they also changed the morphodynamic behaviour of this coastal stretch. A common feature over the entire time frame is the presence of a multiple bar system along the entire length of this stretch of coast. A distinct difference in bar behaviour can be observed between the 1965-1990 and 1990-2011 periods. Prior to 1990, we observe a multiple bar system with a well-defined bar along the beach and an offshore bar that...
shows a repeating pattern of offshore migration followed by the disappearance of the outer bar, with a bar-cycle return interval of about 15 years. Since 1990 we cannot clearly observe cyclic or repetitive bar behaviour: there is a reasonably stable bar system with two well-defined breaker bars. The offshore breaker bar remains stable in its position, although the bar height varies over time. There is a well-defined inner bar between the outer bar and the beach. This inner bar is characterised by complex alongshore structures. Bars seem to bifurcate randomly and parts of the inner bar merge with the outer bar.

Interestingly, south of Egmond the nourishment operation was on the beach instead of the shoreface. Here we observe a continuous pattern of offshore migrating breaker bars. As the outer bar decays, the inner bar takes over its role and a new inner bar is formed along the beach.

Further reading
Severe floods have caused extensive damage and loss of life throughout Europe in recent decades. The magnitude and the short recurrence interval of large events has raised questions about the current safety standards for flood protection. In response, the 1/1250-yr design flood for river dikes in the Netherlands was raised recently. Given projected climate change, and the associated increase in precipitation amount and intensity, it is anticipated that the design standard for dikes in the Netherlands needs to be even stricter. However, a major problem in calculating the discharge of the current and future design flood, and therefore the required dike strengths, is the margin of uncertainty, which is mainly the result of the limited availability of data for predicting the recurrence time of extreme events and of the non-stationarity of flooding regimes. The current discharge record goes back only a century and is presumably only a poor representation of the distribution of extremes over time. Moreover, climate variability and growing human influence (in the form of, for example, deforestation and river management) have resulted in varying flood probabilities over time.

This project aimed to enhance the available data by harvesting information from sedimentary records from oxbow lake fills and dike breach ponds of the Lower Rhine, and cross-validating results with the instrumental records and historical records of the last six centuries. This resulted in a flood magnitude record that stretches back more than 8,000 years. Discharges of palaeofloods were calculated using the correlation established between grain-size characteristics in flood deposits and contemporaneous discharge measurements, and hydraulic modelling based on the elevation of slackwater deposits on high terrace levels in the Lower Rhine Valley. It was found that there
was an extreme flood around 4700 years ago with a discharge of at least 14,000 m$^3$/s. This is considerably more than any measured discharge and reaches values close to current flood protection levels. Several other palaeofloods of a similar size (millennium floods) occurred around AD 1374 and 784, and about 4500 and 6200 years ago. The palaeoflood record suggests a strong temporal variability in the flood regime. In addition to the strong link between flooding and multi-decadal periodicity, there are prolonged periods throughout the Holocene with strongly increased (for instance in the Little Ice Age) or reduced (Roman period) flood occurrence.

The knowledge acquired about flooding regime variability and the magnitudes of extreme events in the past are important for the role played by Deltares in advising the Delta Committee about current flood risk and possible future scenarios. The approach developed can also serve as a benchmark study for other densely populated delta regions, such as the Mekong and Mississippi deltas, which suffer from similar problems.

Further reading
Ecosystems and Environmental Quality

**scope**
Agricultural and industrial activities, and urban development place a major burden on the soil and groundwater system. At the same time, chemical and biochemical processes in the subsoil have a major impact on risks for people and ecology. Changes in chemical and biochemical quality in the soil, in the groundwater and in the associated surface water systems and ecosystems are determined to a major extent by the transport of water. Of course, water quality cannot be viewed independently from the water quantity issues in the next section. Explaining these complex problems, interactions and solutions from an independent role makes up the impact of Deltares.

**background**
The physical geo-ecosystem involves chemical and biochemical processes, as well as physical soil processes. Agriculture, industrial activities and urban development place a major burden on the subsurface. Changes in soil quality and in the associated groundwater and surface water systems and ecosystems are determined to a major extent by the transport of water and the substances present in that water. In addition to system knowledge, management considerations and the development of measures based on this knowledge, in-situ intervention in chemical and microbiological processes is opening up new ways of tackling soil contamination and soil improvement. Furthermore, there are many useful ways of exploiting the subsurface, such as heat/cold storage, the use of groundwater and minerals.
Sustainable land use in rural areas involves the sustainable use of natural resources and the prevention of the unacceptable degradation of soil quality and land use options: whether physical (load-bearing capacity or soil structure, for example), chemical (fertility of the soil, soil pollution) or biological (life in the soil). From the environmental perspective, the concept of Soil Services has been embraced. Besides ecosystem services, the soil supplies groundwater, energy, and space for storage and transport.

This theme covers the links and interaction between the biotic and abiotic components of water and soil systems. Saltwater and freshwater systems are looked at in conjunction. Integration and innovation in chemical, biological and physical knowledge for the description, assessment and prediction of the sustainable functioning of the systems are central. The effect (cause-effect relationships) of natural and human stressors (climate change, for example) is studied so that answers can be given to questions from policymakers, managers and users of the soil and water system.

These issues result in five programmes: From catchment to coast, Ecosystem services, Eco-innovation, Eco-engineering and Next Generation Information Tools.
The IJsselmeer and Markermeer lakes have experienced declines in certain species of waterfowl, including diving ducks and fish-eating birds. EU and Dutch legislation require the authorities responsible for managing water resources to be specific about their conservation objectives. With regard to waterfowl, it was not possible to set science-based targets for conservation because the underlying reasons for the population declines were unknown or uncertain. To address this issue, Deltares implemented a five-year research programme to investigate the causal mechanisms of the downward trends in waterfowl, to study effective measures to counteract the downward trends and their cost, and finally to define feasible conservation goals.

These questions have been addressed on the understanding that contributory factors may include factors, such as climate change, that are beyond the geographical scope of the study site. The study identified the causal mechanisms of declines in organisms in the lakes (mussels and smelt, for instance) and their availability as food for birds as influenced by conditions such as turbidity. Furthermore, the study indicates how these factors affect the numbers of target bird species.

Five PhD students have been working on the subjects smelt, zooplankton, system ecology, suspended materials and aquatic plants. Existing monitoring information and databases from Rijkswaterstaat were used, together with data from specific ANT monitoring campaigns (mussels and smelt) and remote sensing. Six fully automatic monitoring poles in both lakes provided large amounts of data from equipment making continuous measurements. The information collected supported the
application of various detailed (2D-3D) mathematical models for flow, waves, suspended material and algae. The ANT fundamental research has provided the knowledge for the NMIJ consortium, which includes Deltares, to build a more Natural Markermeer-IJmeer, analysing promising measures and field experiments to improve the ecological quality of both lakes.

The study concludes that the decline in food resources is the main cause of the reduction in waterfowl numbers. There has been a large decline in smelt in both lakes and the quality of the food (algae, zooplankton and mussels) has also worsened significantly. In turn, the decline in food resources is mainly attributable to the successful implementation of nutrient (i.e. phosphate) reduction measures in the Rhine river basin over the last 40 years. Climate change is not thought to be an important driver of change in bird densities in the IJsselmeer and Markermeer lakes. Fishing is thought to be an important secondary factor affecting smelt.

Cooperation
WUR
NIOO
IMARES
VU-IVM
TU-Delft

Further reading
Final report ANT - Autonomous Downward Trends in IJsselmeer and Markermeer Lakes, Deltares 2014, (in Dutch)
The eutrophication of aquatic ecosystems caused by diffuse nutrient loads is a widely recognised water-quality problem in catchments, inland lakes and coastal areas. Diffuse phosphate fluxes originate from surface runoff and flows from groundwater into surface water. However, these surface waters act as filters and not all nutrients that enter a stream or ditch will leave it. This can be the result of physical, chemical or biological processes and the nutrients can be retained permanently or temporarily.

The dominant mechanism controlling phosphate retention in lowland catchments such as those in the Netherlands is probably the exfiltration of anoxic groundwater containing ferrous iron. Chemical precipitates derived from groundwater-associated Fe(II) seeping into the overlying surface water contribute to phosphate retention by binding the phosphate to the iron hydroxide that is formed. Measurements reveal that, in a large majority of the surface-water sampling locations in the Netherlands, the total phosphorus concentration is strongly dominated by bound phosphorus, and that iron-bound phosphate is the most important fraction. However, the mechanisms and rates of the iron oxidation process, and the associated binding of phosphates during the exfiltration of groundwater containing anaerobic Fe(II) groundwater are among the key unknowns in the quantification of the phosphate retention processes.
We studied the dynamics of Fe(II) oxidation and mechanisms of phosphate bonding during the exfiltration of groundwater to surface water. Seasonal changes in climatic conditions appear to affect the Fe(II) oxidation process. In the winter, we measured elevated dissolved Fe concentrations and observed typical iron oxide flocks in the ditch. In the summer, the dissolved iron concentrations were low and the ditch water was clear. These observations indicate that changes in temperature and discharges cause a shift in the location of the redox transition zone, with Fe(II) oxidation taking place in the soil around the ditch during the summer and in the surface water during the winter.

Laboratory experiments showed preferential binding of phosphate during the initial stage of the Fe(II) oxidation process. We see that phosphate present during the oxidation of Fe(II) at near-neutral pH values precipitates as an Fe(III)-phosphate mineral phase. A molar ratio of 1 between Fe(II) and phosphate is sufficient to immobilise all dissolved phosphate. As this criterion is commonly met in groundwater that exfiltrates to surface water, we conclude that the formation of Fe(III) phosphates at the groundwater-surface water transition zone is a major factor in phosphate retention in natural waters that drain anaerobic aquifers.
Overfishing, fertilisers, climate change, translocation and coastal engineering appear to preferentially stimulate jellyfish blooms at the cost of other marine life. Jellyfish outbreaks cause losses of tourist revenue, and power outages following the blockage of cooling intakes at coastal power plants. They also have a major impact on fishing, destroying fish catches, killing farmed fish, and reducing populations of commercial fish as a result of competition, predation and the spread of parasites. Given recent jellyfish ‘success’, changing nearby seas (the North-East Atlantic, and the Baltic, Mediterranean, and Black Seas), it is likely that the role jellyfish play in the North Sea will also change.

Inadequate knowledge in the Netherlands relating to jellyfish led to the launch of a research programme by Deltares, NIOZ and Groningen University that is furthering our understanding of the role of jellyfish in the North Sea ecosystem, creating new insights into monitoring and risk assessment instruments, and identifying measures to protect the North Sea. Avoiding the difficulties of traditional jellyfish research, the programme designed and implemented new and more robust techniques to fixate and preserve the fragile jellyfish for quantitative analyses. This knowledge is now being harmonised with other marine research institutes across Europe. During the project, a follow-up was designed specifically to study the invasive jellyfish species Mnemiopsis Leidyi throughout the North Sea and adjacent estuaries and ports, with cofinancing from the EU –INTERREG IVa research programme.

The initial results of the intensive monitoring campaign show that jellyfish species composition and seasonal distribution in the Netherlands have changed dramatically over the last 50 years. Most native stinging species appear 20 to 50 days earlier in the year, and there has been a fall in the populations of virtually all
native species, while M. Leidyi, an invader from the Americas, has established itself firmly in the Netherlands during recent years. This species is now the most abundant gelatinous predator in terms of both biomass and density in the Wadden Sea and Zeeland delta area. Experiments show that M. Leidyi has even greater tolerance to environmental conditions than previously suggested, as illustrated by the fact that it forms large blooms in the brackish North Sea Canal, clogging fishermen’s nets.

Through isotope measurements, gut analyses and studies of growth, feeding, and behaviour, we established a unique picture of the feeding habits, growth patterns and reproduction cycles of the most prominent species. This insight provides valuable information about how jellyfish affect the North Sea and its many users. Jellyfish appear to compete intensively with native zooplankton species (shellfish and fish larvae) and smaller fish, which traditionally shape our North Sea food web. M. leidyi specifically consumes shellfish larvae at high rates. New combined ecological and socio-economic models allow for better predictions of jellyfish movement throughout the North Sea, identifying potential problem areas.

Further reading
A monitoring system to identify more precisely the sources of substances like nitrates in agricultural areas is key to assessing the impact of agriculture on the quality of surface water. In a project commissioned by the National Institute of Public Health and the Environment (RIVM) and the Dutch horticulture sector organisation (Productschap Tuinbouw), Deltares worked with SorbiSense and Alterra to develop a simple monitoring system that records both flow volumes and the quantities of solutes present in drain water: the Flow-Cap.

The Flow-Cap is installed in agricultural drains or discharge pipes from greenhouses. It directs a fixed proportion of the total discharge flow through a SorbiCell, a device patented by SorbiSense that records the amount of the target substance and the volume of the water flow. After a given period of time, the SorbiCell is analysed in the laboratory to determine the cumulative pollutant load during the installation period. The monitoring system does not need a power supply, and installation and removal are straightforward, making the device easy to use in a wide range of locations.

Laboratory tests showed that the Flow-Cap works as intended and field tests to measure nitrates were performed with the Flow-Cap. Until now, there has been no easy way of measuring amounts of pollutants exiting an agricultural drain or discharge pipe with the discharge water. The alternative—taking samples and subsequent analysis—
– produces ‘snapshot’ concentrations in flows that are usually very variable. In addition, the concentrations have to be linked to the flow volumes to determine the pollutant loads and the actual impact of the discharge on the water system.

RIVM manages the national network that is used to monitor the impact of the Fertiliser Policy. RIVM was therefore looking for a simple method to continuously measure the quality of water from drainage pipes in agricultural locations. On the basis of the initial field results by RIVM, the Flow-Cap has already been adapted to make it more user-friendly. RIVM now intends to try out the Flow-Cap on other soil types in their monitoring network.

The Flow-Cap has also been tested in a greenhouse location and on a test farm. It proved necessary to make specific decisions about the right dimensions and the best approach to installation at each test location. At present, the system can be used for nitrate only. Further testing will be necessary for other types of discharge pipes and other solutes. Possible applications are the monitoring of run-off from farmyards and discharges from mobile units for medical screening.

Further reading
Europe has a dense network of rivers. From an ecological perspective, rivers and their floodplains are some of the most diverse ecosystems in the world. However, the increasing use of rivers over time has resulted in the severe degradation of ecosystem functioning. A recent analysis of the River Basin Management Plans (RBMP) for the EU Water Framework Directive (WFD) indicated that 40% of European rivers are affected by hydromorphological pressures generated predominantly by hydropower, navigation, agriculture, flood protection and urban development. In reaction, there is now an increasing focus on restoring river hydrology and morphology. The ecological response to hydromorphological restoration, however, is complex and poorly understood. It is therefore very important to establish a better understanding, and to predict the costs and benefits, of river restoration.

Against this background, the EU-funded FP7-project REFORM is the first international research project to provide guidance and tools for successful and cost-effective river restoration. The consortium of 25 partners from 14 European countries represents a wide range of disciplines: hydrology, hydraulics, geomorphology, ecology, socio-economics, and water management. The ultimate goal of REFORM is to generate tools for the cost-effective restoration of river ecosystems, and for the improved monitoring of the biological effects of physical change by investigating natural, degradation and restoration processes in a wide range of river types across Europe.
At first, REFORM reviewed existing information about hydromorphological and ecological assessment methods, hydromorphological degradation, and hydromorphological-ecological interactions related to river restoration. The main shortfall in most of the assessment methods is the inadequate consideration of physical processes in the assessment of hydromorphological conditions. Conceptual schemes have been developed to connect drivers, pressures and affected processes. This has resulted in sets of indicators to detect different impacts.

A great deal of emphasis has been placed on communications and dissemination. REFORM operates in close contact with the ECOSTAT working group of the Common Implementation Strategy of the WFD. There is also direct interaction with the European Centre for River Restoration, which has the largest network of practitioners in Europe. An interactive workshop for 120 stakeholders was organised to inform stakeholders about the initial results and also to consult them about the key topics related to river hydromorphology and ecological status. In addition to expanding the knowledge base, there is also an urgent need to share experiences. REFORM has therefore developed a wiki that will be filled throughout the course of the project with information about river hydromorphology, ecology and ecosystem services, as well as restoration methods, cost-benefit analysis and other planning tools.
The soil and groundwater of the Rotterdam harbour area have become polluted as a result of long-term and large-scale industrial activities. This pollution is extensive and complex, and it is also a cross-boundary problem locally. Dealing with pollution on a case-by-case basis is not very cost-effective. Deltares has therefore opted for a joint mega-site approach, as management strategies can then be orchestrated and measures prioritised.

By taking into account the natural resilience of the soil and groundwater system, it is possible to determine which pollutants are critical and should be dealt with. The mega-site approach also makes it possible to combine spatial planning, such as the redevelopment of industrial locations, water management and subsoil use, while eliminating the risks of large-scale ground and groundwater pollution. Three hypothetical interfaces have been set up for the Rotterdam harbour project to quantify the risk of the dissemination of pollution to groundwater and surface water in terms of Planes of Compliance (PoC). PoC1 is the interface between the harbour area and the surrounding surface water, PoC2 is the interface between the Holocene layer and the Pleistocene aquifer, and PoC3 consists of the harbour area boundary. The risk of exceedance of the legal intervention values for pollution can be determined for these PoCs. In addition, it is possible to determine the effects of possible remediation measures such as source removal, pump & treat and stimulated biodegradation.

For the purposes of this research, we developed a groundwater flow and transport model (MODFLOW, MODPATH, MT3D) for the harbour of Rotterdam.

Groundwater contaminant modelling and risk assessment
This model shows the risks and uncertainties of contamination at the planes of compliance in the future. On the basis of this risk information, an optimised monitoring network was installed at the harbour boundary. This model is also used for remediation measures to be taken inside the area in order to prevent spread outside the planes of compliance. Different goals require different scales: a large-scale grid can be used for an overall risk calculation for the complete area, and a very detailed small scale for calculations for specific measures.

The transparent, user-friendly interface iMOD is used to serve the many different stakeholders in the area. This interface was developed by Deltares to handle very large models. The graphical tools of iMOD give all parties the opportunity to examine the input parameters such as contaminant concentrations and degradation parameters, and to see the predicted spread of the contaminants. In this way, it is possible to encourage ownership of the mega-site approach, and optimised monitoring and measures can be discussed by parties with different interests.

Further reading
https://publicwiki.deltares.nl/display/IMSW/
Singapore is one of the most densely populated countries in the world. It has an important coastal environment despite its small land area (710 km²). Singapore’s coastal waters are used intensively for recreational activities, port and shipping activities, maritime and petroleum industries, and fishery and aquaculture. The Singapore National Environmental Agency (NEA) manages water quality in Singapore’s coastal environment, regulating and monitoring pollution in all surface waters, and safeguarding recreational beach water quality. In 2011, NUS-Deltares entered into a Cooperative Research Agreement with NEA to develop an Operational Management System – Neptune OMS – for the coastal waters of Singapore.

The key concerns of NEA include maintaining good coastal water quality for recreation and fisheries, including aquaculture, supporting ecosystem health, and preserving mangroves, seagrass beds and coral reefs. NEA is the lead agency in the response to fish kills, algal blooms or other water quality concerns, and it coordinates with the Marine and Port Authority in the event of chemical or oil spills. Accurate and up-to-date information on coastal waters is essential for all these activities.

For the Neptune OMS, NUS-Deltares has focused on developing, implementing and validating a national water quality monitoring and prediction service to support NEA in the management of Singapore’s coastal waters. Accordingly, it is developing a monitoring network made up of eight buoys strategically...
deployed around Singapore’s coastline that monitor water quality in real time. These buoys, together with a hydrodynamic and water quality modelling framework, have been integrated in an Operational Management System (OMS) to provide detailed information about current and expected water quality status. Deltares FEWS and Delft3D software systems are being used for the implementation of this system as a whole.

The OMS will serve as a complete operational tool for processing, archiving and visualising water quality data, providing updates on current and forecasted water quality trends, and providing details about the required management responses based on operational rules and mitigation strategies.

The water quality parameters included in the system focus on key eutrophication parameters: dissolved oxygen concentration, nutrient concentrations (including total nitrogen, ammonia, nitrate, total phosphorus and phosphate), phytoplankton biomass (as chlorophyll-a) and suspended solids (turbidity). In addition, bacteria (F. coli, E. coli and Enterococci) are modelled as these are critical for recreational water quality. In addition, the framework also includes the capability to model accidental spills of oil or chemicals.

The real-time operational Neptune OMS system will be installed at the NEA in Singapore, with a back-up system at the National University in Singapore (NUS). Capacity building and training are part of the cooperation agreement so that NEA can use the system independently with access to call-out support from NUSDeltares.
The Water Framework Directive (WFD) is one of the most important policy directives in Europe for the improvement of water quality and ecology. Deltares worked together with numerous partners to develop a new software tool to help water managers to assess proposed measures and evaluate results.

The WFD Explorer is an analysis tool designed to support the implementation of the WFD. The tool makes it possible to calculate the effect of restoration and mitigation measures on the ecological and chemical quality of surface waters. Users can see how effective programmes of measures are in relation to WFD objectives. Measures can be defined in relation to point sources such as wastewater treatment plants and diffuse sources such as agriculture and traffic. Similarly, it is possible to calculate the effectiveness of restoration measures such as stream re-meandering or the construction of near-natural riparian zones. A cost module is available to calculate and map the costs of measures, making it possible to assess the cost-effectiveness of different programmes of measures.

Users can easily import or adjust their own schematisations, emission data and area-specific characteristics. The user-friendly user interface makes it easy to set up a model structure, perform an analysis and produce reports, maps, and exports.
reports in an organised and systematic way. Those reports can then be used in policy briefings, for communications with stakeholders and as background documentation for reports to the European Commission.

The WFD Explorer contains models for hydrology and water quality, and an ecological module. Monitoring data can be used instead of model results as input for the ecological module. The new ecological module focuses on biology, using four biological quality elements (macrophytes, benthic invertebrates, fish and phytoplankton) that, taken in conjunction, provide an indication of ecological status. In the WFD, this ecological status is quantified as the ecological quality ratio (EQR score), which can be calculated in the WFD Explorer for each water unit. The tool helps to stimulate and structure the development of ecological knowledge.

Partners:

Further reading
www.krwverkenner.nl
Dutch and German water managers are working together for the first time to explore ecosystem services that will be created by river restoration measures and to determine how payment for ecosystem services (PES) can help to maximise societal value.

The ‘Vecht Vision’ (www.devecht.eu) describes an approach for turning the Vecht back into a beautiful, safe river with clean water, healthy flora and fauna, and for creating a prosperous economic environment. Water managers and local policymakers welcome new ideas and initiatives to realise that vision. This was the opportunity to initiate a trans-boundary, Dutch-German research project looking at ecosystem services in 2011.

The project started by identifying the ecosystem services that local residents living near the Vecht river in the Netherlands and Germany consider to be important. This was done by interviewing, on both sides of the border, individual stakeholders from agriculture, water management, tourism, municipality and nature protection. This revealed – as expected – that they value ecosystem services differently.

In 2013, the project continued to examine how these individual stakeholders value ‘their’ ecosystem services and how these values will be affected by the dike realignment with the aim of restoring floodplains and creating more space for the river. This was done by organising additional interviews, followed by a series of intensive workshops with the stakeholders, in which communications were facilitated by arranging simultaneous translation. Furthermore, the stakeholders worked together to quantify how individual interests may be affected by dike realignment. This process included drawing on knowledge sources (scientific and other) from the outside. It therefore became clear to the stakeholders that there will be ‘winners’ (beneficiaries) and
‘losers’. More space for the river will result in more biodiversity, making the river more attractive and attracting more tourists, and therefore generating more income for the tourism sector. However, farmers, on whose land the space for the river is likely to be found, will lose farmland or face restrictions. There are also potential trade-offs between nature development and tourism. This means that compensation mechanisms will be needed to achieve a balance between the costs and benefits for stakeholders.

These compensation mechanisms will have to be explored in the future. A proposal for a ‘payment for ecosystem services’ (PES) scheme will be discussed, negotiated and – where feasible – approved in a final workshop with the stakeholders. During the course of the project, the water managers concerned have already been informed that an ecosystem services approach may help them to find: (a) better integrated solutions to the problems in the area, (b) new funding opportunities for measures and (c) more acceptance and support from land-owners and the public for these measures.

The project is being conducted by a German - Dutch (Deltares) research team in close cooperation with the local water managers and municipalities.

Finance
Ministry for Infrastructure and the Environment, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Niedersächsisches Ministerium für Umwelt, Energie und Klimaschutz.

Further reading
Van der Meulen, S et al., 2012. Towards practical implementation of the ecosystem services (ES) concept in transboundary water management (available at kennisonline.deltares.nl)
To become less dependent on fossil fuels, the world will turn to a more bio-based economy over the next few decades. This change will be accompanied by a change in land use to produce crops for bio-based applications (such as fuels and bio-plastics), affecting adjacent water bodies like agricultural ditches. The sediments in these freshwater systems are hotspots of microbial activity and are important for global nutrient cycling and greenhouse gas emissions. However, it is largely unknown how microbial diversity and activity are affected by higher eutrophication levels and pesticide use brought about by bio-based associated activities.

In this project, Deltares is working in close cooperation with the Netherlands Institute of Ecology (NIOO) and Bioclear to develop a fast and cheap tool to effectively monitor the effect of bio-based inputs on freshwater ecosystems.

The approach taken is based on the presence of functional genes of micro-organisms that catalyse processes influenced by agricultural run-off (nutrients, pesticides, etc.) which are therefore linked to eutrophication and pollution. The project uses a DNA screening tool (GeoChip) that makes it possible to monitor all genes involved in major elemental cycles, pesticide degradation, antibiotic resistance, heavy-metal metabolism etc. The observed correlations are used to design a tool for the efficient evaluation of the biogeochemical functioning of aquatic systems in response to land-use changes.

A set of 50 drainage ditches in the Netherlands representing a wide spectrum of nutrient status...
were used as the reference set for the research. The sediment and water samples were analysed for biological and physicochemical parameters such as microbial activity, organic matter content, concentrations of major elements, granulometry. Information about the levels of 132,000 genes at each of the sampling sites became available after GeoChip analysis in the laboratory of Environmental Genomics, Norman, Oklahoma (USA). A strategy was developed to retrieve the relevant information from this enormous dataset, and the analysis is ongoing. Finally, qPCR assays for ‘indicator’ genes will be developed to identify the impact of land-use change efficiently.

A second line of research in the project was started in parallel at the Deltares laboratory for microbiology. This involved manipulating the nutrient and pesticide concentrations in controlled sediment incubations. For the selected pesticides (imidacloprid, glyphosate, metribuzin, and azoxystrobin) it was shown that the microbial functions were already affected at Dutch norm concentrations. On the other hand, the microbial community recovered very well after exposure. The possibility of using microbial functional genes as bioindicators for the presence of pesticides merits further investigation.

Further reading
Marcelle van der Waals, 2013, The effects of pesticides in a bio-based economy on microbial functions in the sediment, Master’s Thesis, Deltares/ Utrecht University
Economic activities and climate change are increasingly affecting the condition of rivers throughout the world. This requires a new, integrated approach towards river basin management that can also cope with an uncertain future.

Leading European scientists and representatives of major stakeholder groups present this new approach in “Risk-informed management of European River Basins”. The book was developed in the EC-funded project RISKBASE coordinated by Deltares. The approach aims to improve the ecological quality of river basins and therefore to maintain the goods and services they provide for the benefit of society. Risk-informed management involves the integrated application of three key principles: being well informed, managing adaptively, and pursuing a participatory approach.

A sound, evidence-based understanding of the functioning of the soil–sediment–water ecosystem and of its interaction with the social system is the basis for river basin management. A useful conceptual model for understanding the risks affecting river basin ecosystems is the ‘Sources-Pathway-Receptors’ model. In any river basin there are numerous sources of risk, and pathways where risks can be propagated through the basin and subsequently reach receptors, in other words the goods and services provided by the river ecosystem.

Using our best available understanding of how river ecosystems function will certainly improve river basin management. However, uncertainties will always remain. This is intrinsic to
both social and ecological systems. Systems, especially at larger scales, are complex and dynamic, and they can respond in non-linear and unexpected ways. We may be able to cope with these uncertainties by applying the concept of adaptive management, which can be described as ‘learning by doing’ or ‘learning to manage by managing to learn’.

Participatory processes involve stakeholders in management with the aim of enabling them to exchange their views and opinions on problems and bring their knowledge to the table. Learning together to understand the land–water system in a better way makes it possible to find better solutions. This process of social learning requires a common language. The rapidly developing ecosystem services approach may provide that language. A common understanding of the value of the goods and services that a healthy ecosystem can provide, and how their present poor status due to our actions can be improved, is the key to a new approach to river basin management.
Water management means ensuring that there is enough clean water of the right quality for agriculture, the public and industry, sharing the water when there are shortages, and preventing damage and nuisance when there is too much water. Throughout the world, changes in land use and the climate are resulting in both water shortages and excess water. In the Netherlands, changes in legislation and regulations in the area of spatial planning, in combination with these trends, require drastic measures. In the past, Dutch water management has focused primarily on the rural area from the perspectives of agriculture (drainage) and nature areas (raising water levels). However, the future of the densely-populated and water-rich Netherlands requires practical knowledge to help with water management in urban areas too. Water managers have discovered the city, and municipal authorities and project developers have in turn discovered the value of water.

As the subsoil forms the bottom layer of our ecosystem, with long characteristic time scales, subsoil management has a specific
responsibility with respect to the sustainability of measures. The use of soil as a building material leads to irreversible changes on the surface. The use of the subsoil to store heat and cold raises questions about interference and spatial planning in the subsoil.

New regulations and changing ideas are leading to an increasing need for a coherent picture based on different perspectives. This is where Deltares can have real impact. Good communications with water managers are at least as important as scientific knowledge. Matter experts must be able to provide support for decision-making processes in the short term (operational management) and the long term (policy preparations). Thinking in terms of water levels and subsoil use should shift to thinking in terms of costs and benefits.

The programmes in this theme cover water and soil: River basin management, Fresh water supply in urbanising deltas, Sustainable energy from water and subsoil and Characterisation and visualisation of the subsoil.
Interactive modelling

The conventional approach to setting up and updating numerical models usually takes between several hours and several days. What if we can complete this process instantly? How can we adapt models so that we can edit model input, run and visualise results at the same time?

Interactive models are becoming increasingly available as online or desktop applications which are mainly used for demonstration and educational purposes. These models often simplify the physics behind flows and run using simplified model geometries. The primary value of these models is heuristic. In other words, they should primarily be used for qualitative, exploration purposes.

How different is interactive modelling from conventional modelling? What are the main characteristics of interactive models? In what situations should interactive models be used instead of the conventional approach?

Turning existing (generally conventional) model engines into interactive engines starts with some important basic concepts. The engine does not run the model from start to end, but is always available in memory, and can be fed by new state changes at any time. These changes may include new boundary conditions and state variables such as bathymetry, roughness or even the spatio-temporal grid. Moreover, the Hollywood principle (“Don't call us, we’ll call you”) is applied, making it possible to input instructions for the model engine from the “outside”, instead of the model engine initiating all the necessary actions itself. This makes it
possible to develop new ways of using numerical models, mixing them with advanced computer graphics libraries to provide photorealistic visualisation, even during the model run.

One of the applications of this approach is the interactive D-FLOW interface. The prototype software uses the new D-FLOW Flexible Mesh numerical model, which is being developed at Deltares in the context of the Next Generation Hydro Software Project. The model can simulate hydrodynamics, including salinity transport. To achieve an interactive modelling experience, the model was turned into a library from a stand-alone executable. Additionally, a very thin Application Programming Interface was implemented in the model, enabling introspection. Furthermore, a simple graphical user interface was developed to integrate the model engine with a scientific visualisation tool kit. The user can make changes to the model state variables during the simulation and in the design process for dikes and harbours and immediately see the effects of these changes in the model results.

The obvious benefits of interactive modelling are that it allows much shorter feedback loops in the modelling process. This allows for a much better understanding of the processes that are simulated by the model, and also of the limitations of the model. The user can focus on the physical processes to be simulated instead of the file formats and conversion tools: what you see is what you model (WYSIWYM).

Further reading
Aquifer thermal energy storage (ATES) is the storage and recovery of thermal energy in the subsurface. A basic ATES system consists of two groundwater wells and operates in a seasonal mode. In the summer, cool groundwater is extracted from one well and used to cool a building or facility. The heated groundwater is injected back into the aquifer through the other well, typically 100 or 200 metres away. This creates a store of heated groundwater. In the winter, the flow direction in the system is reversed: the heated water is extracted and can be used for heating purposes and, at the same time, to create a store of cooled water in the subsurface. Larger systems may consist of more wells. In the Netherlands, ATES is already used as a standard technique for utility buildings such as offices, hospitals, and public buildings. The number of systems has increased from 5 in 1990 to 2740 in 2012, resulting in a total flow rate of 248 million m³ groundwater per year. Given increasing demand for sustainable energy and rising concerns about fossil fuel use and CO₂ emissions, this trend is expected to continue in the future.
If the distance between the warm and cold stores is too small, thermal interference results, impairing system performance. Due to limited space in urban areas, thermal interference between wells is a major concern in terms of the widespread application of ATES. To facilitate optimal use of the subsurface, some municipalities in the Netherlands have issued master plans that regulate the positioning of the wells for storing thermal energy. Deltares is now developing a method to determine the optimal well spacing for the widespread application of ATES. Over-generous well spacing leads to the suboptimal use of available aquifer volume, while inadequate spacing causes thermal interference. Subsurface heat transport modelling is being used to determine thermal efficiency for different zonation patterns and well distances. Life cycle analysis is being used applied to determine the effect of thermal interference on costs and CO$_2$ emissions over the lifetime of the system and to compare ATES with a conventional heating and cooling system.

Further reading
Renewable energy sources such as wind and solar power are hot topics nowadays. However, most domestic energy consumption is for heating and cooling. Major savings can be achieved with integrated renewable energy sources or by using surplus heat from power plants in district heating systems. However, the challenge is to integrate renewable sources (geothermal, solar), which only produce low-grade (80°C) heat and district heating systems which are designed for high-grade heat (120°C).

Deltares is working with Imtech, Priva, Deerns and Delft University of Technology on a research project for a smart thermal grid. The goal of the project is to design and implement a smart control system for the district heating system of the Delft University of Technology. This control system needs to be optimised to include the full potential of a planned 5MW geothermal well. To design this control system, simulations are being performed with the software packages LEA and Wanda 4 heat.

LEA (Low-Energy Architecture) is a building design package developed by Deerns that can be used to calculate the energy usage of buildings. Wanda is the dynamic pipeline simulation tool developed by Deltares that also includes temperatures. LEA is being used to calculate the heat demand for each building at the Delft University of Technology. The results are being used to
investigate which buildings can cope with low-grade heat after some minor changes to the building heating system. The results of these calculations are then being used in Wanda 4 heat to simulate the complete district heating system of the campus in Delft. The return temperature and flow at the heat production plant is being calculated. To ensure the full potential of the geothermal well is used, the return temperature should be as low as possible and preferably below 40°C. The simulation can be used to achieve this by changing the controls and using the internal heat storage of the buildings (smearing of the peak in the morning). One of the four heating loops supplies heat to one third of the TU Delft buildings. The first results show that this loop can use up to 6000 GJ of geothermal heat per month. This is half of the 5 MW which has to be delivered at least by the geothermal well for a balanced business case.
Fresh groundwater in coastal areas throughout the world is a popular water resource for domestic, agricultural and industrial activities due to its availability and its high quality relative to surface water. For the future, the use of fresh groundwater resources is likely to increase due to population rise (especially in megacities), economic growth and intensified agricultural development and due to loss of surface water because of contamination. Salinisation affects exploitation of groundwater for drinking water purposes, for agricultural use and nature conservation. In addition, sea level rise and the associated changes in recharge and evapotranspiration pattern will intensify the pressure on the coastal groundwater.

In the south-western delta in the Netherlands, the agricultural sector is confronted with growing impacts of water shortage and salinization. The agricultural sector and municipalities consider a reliable freshwater supply as one of the key issues for future development and sustainable growth. The local government is aware of the negative influence on the socio-economic development and, on a national level, strategies to reduce freshwater demand and increase freshwater supply are being developed within the Delta Programme.

The main goal of the project GO-FRESH (Geohydrological Opportunities for FRESH water supply) is to improve the use of existing fresh groundwater resources and create new freshwater reserves, thereby increasing regional self-sufficiency and reducing dependence on external freshwater supply. Research
already takes place on the technical feasibility of possible measures. Building on this knowledge, the research goals are now to investigate which measures actually ‘work’ in practice, and to analyse whether such measures are economically feasible.

We develop showcases of three promising technologies which increase local or regional water supply. Two showcases are set up on aquifer storage and recovery (ASR), utilizing the potential of sandy creek ridges for water storage, called The Freshmaker and the Creek Ridge Infiltration Test. The third showcase concerns optimising the freshwater volume in shallow rainwater lenses in the pilot Drains2Buffer. The focus of the showcases is on integration of new knowledge, stakeholder participation and opportunities for practical implementation in the region including the economic feasibility analysis.

Cooperation
Province of Zeeland
Municipality Schouwen-Duiveland
Regional Water Authorities Scheldestromen and Brabantse Delta
Agricultural sector organisation ZLTO
STOWA water research

Innovative French monitoring system from ImaGeau
The subsurface of the village of Kockengen consists of peat deposits up to 6 m thick, and substantial land subsidence is an increasing problem. Roads are subsiding by up to 45 mm/y, and differential settlement is leading to the disconnection of sewage pipes and therefore the large-scale drainage of groundwater and a substantial loss of sewer capacity. The consequence is increased street flooding during heavy rainstorms. Residents and public parties have initiated a planning process with the aim of developing strategies to slow down subsidence. Deltares contributed to strategy development by applying a recently-developed rapid urban water assessment model, SWB.

The maintenance of sufficiently high groundwater levels is essential to slow down land subsidence. Effects to be taken into account in the groundwater balance are climate change, with more severe and more frequent dry summers, the planned downward adjustment of surface water levels by 15 cm in the surrounding polders and the renewal of the sewage system, which will greatly reduce groundwater drainage into the leaking sewers. The SWB model was applied to quantify the net effect of these opposing trends on local urban groundwater quantities.

The SWB model conceptualises the urban (or village) water system as a set of reservoirs, each representing a subdomain: vegetation, land surface, sewer, unsaturated zone, saturated zone, and surface water. Regional water systems are parameterised as lateral and bottom boundary conditions.
Internal variations of model parameters within the area are not taken into account. While detail may be lost as a result of this approach, it greatly speeds up pre- and post-processing and calculations. Furthermore, monitoring density for water-related parameters is often too low to justify more detailed modelling.

The model was tuned using historical monitoring data supported by high-frequency discharge data (2009-2010) for the Kockengen sewage pumping station provided by the Stichtse Rijnlanden water authority. This proved crucial to achieving a fair match between the model and reality, and made it possible to draw up the urban water balance for the present situation. A striking feature is the dominance of groundwater leakage into the sewer and, as a consequence, its replenishment with surface water.

After the tuning of the model, scenarios were simulated for climate change, surface water level adjustment and sewer renewal. They show that groundwater conservation resulting from the renewal of the sewers should be sufficient to offset the combined effects of surface water level adjustment and the climate scenario, even in an extremely dry year. However, this does not lead to a straightforward solution because groundwater conserved in the wet winter season cannot be retained until the summer without causing waterlogging and it is therefore of no use as a way of slowing down subsidence. The results of this study therefore illustrate the need for the innovative, adaptive management of urban water and infrastructure.

Further reading
**scope**

Sustainable living in delta areas requires an understanding of building on and in soft soils. Underground construction, and onshore and near shore transport infrastructure, contribute to a habitable and prosperous country. The private sector is the important actor in realising these opportunities. Increasing innovations in enterprises and reinforcing the Dutch knowledge-based economy make up the Deltares impact in this theme.

**background**

Pressure on the available space is increasing. Minimisation of environmental impact requires innovative and sustainable solutions, incorporating knowledge of natural processes. As the limits of what is possible or desirable onshore and above ground have been reached, the sea and the subsurface are increasingly coming into the picture.

Worldwide developments like climate change, sea level rise and land subsidence require development of adaptation measures for new and existing infrastructure. The increase in sea shipping transport and spatial demands in coastal areas are the driving force behind the expansion of ports, construction of breakwaters, land reclamation, and artificial islands. Rising demand for energy requires oil platforms further offshore and wind turbines in the nearshore area. Onshore, the “third dimension” is increasingly coming into the picture during the urban planning process.
However, public willingness to tolerate nuisance during both the construction and operational phases of the required transport infrastructure is steadily declining. In addition, the construction sector has acquired a negative image in terms of cost control and planning. These problems are closely related to a lack of risk management, with the soil and subsurface being a major factor.

Some of the projects in this theme map are being implemented as Joint Industry Projects (JIP). The private participants determine the scope in a project of this kind, and the Ministry of Economic Affairs supports these projects through research grants for Deltares. The knowledge products initially benefit the participants but, in a broader sense, they support the knowledge position of the Dutch corporate sector abroad as hydraulic engineering is a major Dutch export product.

Eight programmes have been defined in this theme. *Ports and waterways*, *Offshore engineering*, *Coastal and river structures* and *Coastal developments* focus on the ‘water’ aspects and the water-soil interaction in this theme. *Underground construction in urban areas*, *Roads and railroads in delta areas* and *Industrial systems and infrastructure* concentrate on different types of linear infrastructure. *Subsidence* addresses effects and mitigation measures for the worldwide problem of sinking cities.
At 2800 kilometres, the Danube is the second longest river in Europe, with 2400 kilometres being navigable. It is one of the important inland waterways in Europe and has been designated as a priority axis. It creates a pan-European inland transport link from Rotterdam to the Black Sea. In Romania, the Danube consists in part of two arms, the Old Danube and the Bala - Borcea Branch. The main navigation branch, the Old Danube, does not meet the official criteria for navigation (minimum depth of 2.5 m and a width of 150 to 180 m) for some 150 to 160 days a year. On those days, the navigation route is diverted through the Bala – Borcea arm, where there are some bottlenecks due to the limited width of the fairway and sharp bends in the river. This detour increases the distance to the entrance of the Danube-Black Sea Canal by some 110 km. To safeguard the navigability of the Old Danube, maintenance dredging with a volume of over 1 million m³/yr is routinely carried out but this has only a short-term impact. The River Administration of the Lower Danube Galati (AFDJ) has decided to implement engineering measures at a number of critical locations to improve the navigability of the Old Danube.

However, the Danube River houses some of the most important sturgeon populations in the world. Sturgeon is one of the endangered animals on the red list of threatened species of the International Union for Conservation of Nature (IUCN). Danube sturgeons live mostly in the Black Sea and migrate up the Danube to spawn. The AFDJ has
therefore commissioned a team led by the National Institute for Research and Development in Environmental Protection of Romania to monitor the environmental impact of the proposed engineering measures. Deltares is carrying out the modelling for the project and this work includes training and capacity building for the local staff.

One of the proposed measures involves building a submerged sill across the Bala branch. The flow velocity over the sill is expected to be higher than without the sill. Accordingly, there is a risk of conditions being created that are will interfere with sturgeon migration. In order to evaluate the effect of the sill on flow velocity, we constructed a three-dimensional hydrodynamic model using Delft3D. The model covers the bifurcation (Bala-Old Danube) over a total section of nearly 30 km. We evaluated the primary function of the sill (diverting more water to the Old Danube) and we looked closely at the flow velocities in the vicinity for different discharge conditions as a proxy for the suitability of swimming conditions for sturgeon. The results have been used to advise the river authority about the function and impact of the proposed works.

Further reading
http://www.afdj.ro/rmd_en.html
The HKND Group, a Hong Kong finance group, has commissioned a study to examine the feasibility of an inter-oceanic shipping canal across Nicaragua as an alternative to the Panama Canal. The canal will cross a ridge and Lake Nicaragua, which is a large freshwater body in the centre of the country. Like the Panama Canal, the Nicaragua canal will require locks on either side of the ridge to sustain the water level in the lake. Deltares has been contracted by SBE NV Belgium to contribute to the feasibility studies for this project of unprecedented scale. The canal may even be designed to accommodate container vessels of sizes expected in the future. This means that the Nicaragua canal will be suitable for vessels larger than those which can go through the Panama Canal, even after the ongoing extension of that canal.

The lock operations will have a number of side-effects that need to be controlled for the plans to be feasible. These relate mainly to the use of fresh water for the lock operations - each upgoing ship passage requires the lock chambers to be filled with water from the lake - and to salt intrusion into the canal and into Lake Nicaragua. The overall channel dimensions needed to accommodate the ships of the future also need to be established.

Detailed modelling has been performed to determine the hydrological characteristics of the area and freshwater availability in both average conditions and during extreme dry events such as El Niño. Archived local measurement data and remote sensing observations have been collected and calibrated to serve as input
for these computations. The results have been used to verify whether using fresh water for the locking process will not negatively influence the lake levels generally and also during dry spells. This verification process showed that there are specific design choices available for the channel and locks (scenarios) that keep the impact on the lake level very limited. These design choices will be considered further by HKND in the subsequent stages of the project.

Salt intrusion levels have also been examined since salt water may intrude from the ocean into the canal system with the ships entering and leaving the locks. Deltres also suggested possible mitigating measures to reduce salt intrusion such as hydraulic barriers (bubble screens) and innovations in lock designs in case these may turn out to be required, and evaluated their potential effectiveness in this particular situation.
Gravity-based structures for offshore wind turbine foundations

With offshore wind parks moving into deeper waters, alternative foundations need to be found for the monopiles in general use. Alongside jacket foundations, Gravity-Based Structures (GBS) are thought to be cost-efficient alternatives in the water depth range of 30 to 50m. This support structure concept is based on a combination of a steel pile and a concrete base that can be mass produced on a dedicated onshore site and floated to the wind park, where it is submerged by adding ballast. A major advantage of this concept is that no piling is required, significantly reducing noise levels (a potential source of harm for marine mammals) during installation. In addition, no heavy-lift vessels are needed.

In the offshore oil & gas industry, there is extensive experience with GBS platforms. However, particularly because of the varied loading conditions and installation methods, several research questions still remain about the use of GBS foundations in the offshore wind industry. In a joint research project with the contractors Van Oord and BAM, and the energy company RWE, Deltares investigated these aspects, and many others, applying a combination of physical and numerical models. The study is part of the FLOW research programme (Far and Large Offshore Wind energy, flow-offshore.nl). The programme is intended to accelerate the construction of wind farms far offshore (>50 km) by developing new, innovative technologies, and therefore carving out a leading position for Dutch companies on the international market.

Hydrodynamic response

Several model tests were performed with two GBS scale models (scale 1:45) in the Deltares Atlantic Basin. The need to use...
scour protection was investigated and several scour protection designs were tested. It emerged that major reductions in rock volumes and therefore cost reductions were possible. Wave run-up was investigated in the same tests. Wave run-up can cause damage to access platforms and secondary steel (such as J-tubes, boat landings and ladders). Existing formulae for monopiles were adjusted for GBS structures. These data were also used for the validation of numerical codes such as ComFLOW and openFOAM.

**Geotechnical response**
GBS structures are installed either directly on the seabed or on a filter bed and so the load capacity of the top layer of the seabed is the determining factor. Wave loads on and the cyclic motion of the GBS can affect this top layer. Numerical calculations were performed with the unique DCYCLE program that models pore water pressure generation and dissipation during cyclic loading over many (thousands of) cycles. The results were confirmed by experimental testing and revealed that repeated cyclic loading without complete liquefaction leads to gradually increasing strength of the top layer. In this way ‘small’ storms prepare the structure for the ‘super storm’ forming the design requirement.
Wind energy has an increasingly prominent place in the renewable market both in the Netherlands and elsewhere, and large numbers of wind turbines are therefore being installed in offshore wind farms. These offshore wind turbines are often installed using jack-up vessels that can raise themselves out of the water and work regardless of the sea state.

Deltares and MARIN are executing a Joint Industry Project (JIP) looking at the interaction between ship movement and the impact of the jack-up legs on the seafloor during touch-down. If the spud cans (the footings of the jack-up legs) hit the seafloor with a large impact, for example due to high waves or a hard seabed, damage to the vessel structure may result. A better picture of the sea state and seabed conditions in which jacking operations are still possible may result in more efficient, and consequently cheaper, wind farm installation. This insight is important for the offshore industry to ensure that jack-up vessels can continue to move frequently for wind farm installation.

Deltares is providing the geotechnical input in this JIP and MARIN is supplying the necessary marine technology. Deltares developed a model that can predict the impact of the spud cans on the sea floor. To validate the model, experiments were conducted in the Geocentrifuge in which scale models of the spud cans penetrated a sand bed at different velocities and angles. The main challenge during the experiments was to combine the high acceleration needed for the jack-up tip model to travel at a sufficiently high velocity during the penetration of the sand and the high level of precision. Different spud can configurations

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**Windjack JIP**

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were also tested to get a feel for the influence of the shape of the spud can.

The Material Point Method (MPM) was used to check and extend the centrifuge experiments. This numerical method is being developed at Deltanew specifically for the analysis of geotechnical problems involving large soil deformations. The main idea for these numerical simulations was, on the one hand, to determine the effect of the relatively close proximity of the spud can to the edge of the testing container and, on the other, to look at a number of situations that could not be simulated due to limited centrifuge time.

The results of the Geocentrifuge experiments and MPM simulations are being used to improve the predictive model. The predictive model provides input for the MARIN aNySim program, which determines the jack-up rig’s reaction.

Cooperation
MARIN, Gusto, RWE, Seaway Heavy Lifting, Hyundai Heavy Industries, Keppel Fels, HGO, Vuyk, Van Oord and Vroon
Recent EU targets for renewable energy have resulted in major efforts to make offshore wind power more cost-efficient. Significant cost savings can be achieved by clustering wind farms and connecting them to large offshore hubs with only a single transmission line to shore. Norwegian marine contractor Aibel is presently developing a new platform concept that will act as one of these offshore hubs. Their concept consists of a topside with a power conversion unit installed on top of a steel gravity-based foundation. This foundation will consist of four columns interconnected by a ring-shaped pontoon at the seabed. At 85x85x60m (lxwxh) it will be one of the largest offshore wind platforms in the world.

The platform is intended for typical North Sea conditions with water depths in the order of 20 to 40m. In these waters, extreme waves will result in large forces being exerted on the foundation, and in impact pressures on the column plates. These factors need to be included in the design. In addition, the deck (where there are sensitive electronics) should be out of reach of the largest waves of the design storm. A good understanding is therefore required of the interaction between waves and the platform.

Aibel commissioned Deltares to perform a study to investigate the wave impact loads, slamming pressures and air gap for their platform concept in a wide range of typical North Sea conditions. The unique, complex foundation shape made this a challenging task for which no standard guidelines could be applied. The Deltares approach was to combine the strengths of physical and numerical modelling to assess the interaction
of waves with this platform and to provide the best possible data for the design.

First, a preliminary computational fluid dynamics (CFD) model was constructed. Selected simulations were performed to pre-assess the impact loads and to decide where to locate the instruments in the scale model. A scale model of the platform was then fitted out with force and pressure transducers and installed in the Atlantic Basin at Deltares where it was subjected to a range of hydraulic conditions (regular and irregular waves; two headings and two water depths). The forces, impact pressures and air gap were measured during the tests and the wave-structure interaction was visually recorded using video cameras. After the tests, the CFD model was refined and validated on the basis of the scale model results. Critical loading cases were reproduced and the detailed flow fields causing the impact loads were analysed. Ultimately, the study significantly expanded our knowledge of wave impacts at large offshore gravity-based foundations.

Further reading
At present, parts of Venice are flooded several times per year. Subsidence and sea level rise will aggravate this problem. A storm surge barrier is therefore being built that will protect Venice from floods. Barriers consisting of bottom-hinged gates will be placed in the four tidal inlets to the Venice Lagoon. These gates can be filled with air, floating up and temporarily closing the tidal lagoon and lowering the high water levels in the lagoon.

The bottom-hinged gates will be positioned on large foundation caissons weighing 20,000 tonnes. Strukton Immersion Projects (SImP) will place the caissons in a trench in one of four tidal inlets, the Chioggia inlet, in the summer of 2014. During placement, the caissons will be suspended from a floating pontoon. A physical model was set up at Deltares to study the placement of the caissons, and the influence of currents and waves. The aims of the modelling study were to determine the cable forces, the pontoon and caisson movements, and to use this information to optimise the immersion procedure and determine the conditions in which the caissons can be placed.

The Atlantic Basin at Deltares is a 9m-wide basin in which waves, currents or tides can be simulated simultaneously. Caisson and pontoon models were constructed with the same mass distribution as the real objects to ensure realistic dynamic behaviour. The loads were measured on
all 14 cables holding the pontoon and caisson setup in place. Moreover, six degrees of freedom were measured for pontoon movement using an earth-fixed, measurement system based on laser distance sensors. Wave height, discharge, water depth, and flow velocity were monitored during the tests. Underwater video recordings were made to monitor the caisson movements. Overtopping onto the pontoon deck was monitored visually. Tests with 30 different hydraulic conditions and immersion depths, and a range free decay tests, were conducted.

Characteristic exceedance values for pontoon motions and cable forces were determined. It was observed that the roll motion of the pontoon was limited and had a low frequency. The motions of the pontoon in the horizontal plane, that are not restricted by the caisson, were dominant. Wave conditions in combination with flood currents were more detrimental for the motions and forces than in combination with ebb currents. However, during flood tides, wave heights are also smaller.

The SmIP engineers found that the system behaved realistically and found it very useful to try out the placement procedure ‘on dry land’. The required strength of various parts of the set-up was determined on the basis of the test results. The time percentage available for actual placement was also determined.

Further reading
The toe structure of a breakwater, revetment or dike supports the armour layer and protects the coastal structure from damage caused by scour at the toe. Toe structures often consist of rock material. There are several design formulae for predicting the extent of damage to the toe structure under wave loading given a certain rock size. These design formulae for the required rock size include the effects of the wave height and the water depth above the toe structure. However, these parameters fail to predict the damage accurately and so the existing design guidelines do not define the required rock size in toe structures adequately.

To provide more accurate and economic estimates of the required rock size, toe stability has been studied in physical model tests in the Deltares Scheldt Flume.

The tests and analysis focused not only on the influence of the wave height and the water depth above the toe structure, but also on the roles played by the width of the toe structure, the thickness of the toe, and wave steepness. All these parameters affect damage to the toe. On the basis of the test results, a predictive formula was derived that included these effects. The formula can be used to determine the required rock size in the toe of coastal structures. Another set of design guidelines, in which the toe structure can be seen as a submerged
berm that is part of the main armour layer, can be used for very large toe structures. The figure at right shows the accuracy of the prediction method for the stability of toe structures. Using this prediction method makes it possible to design more economical structures.

As well as looking at toe structures of rock material, the research also studied toe structures based on armour units made of concrete. The concrete blocks were relatively flat and V-shaped. The V-shape means that during run-down, when the seaward drag forces are relatively large, the weight of more than one unit is mobilised since the toe blocks are interlocking. This innovative type of interlocking toe block has been applied in a structure designed by Royal HaskoningDHV and tested by Deltares.

Further Reading
In the context of the upgrading of the sea route leading to Amsterdam, there are plans for a new sluice in IJmuiden. The distance separating the new sea sluice from the existing sluices is small and the tight fit will result in both geotechnical and nautical-hydraulic challenges.

During dredging and piling work for the construction and maintenance of the existing sluices and other structures in IJmuiden, unstable ground behaviour has been frequently observed. In many cases, this involved flow slides. Flow slides are large-scale deformations that may occur in underwater slopes consisting of sand. Vibrations caused by piling or an increase in the incline of a slope as a result of dredging work can initiate a process of this kind, in which a sand-water mixture flows downwards like a thick liquid. During the preparations for the design of the new sluice, an important question is therefore whether safe construction is possible.

Deltares developed the GeoRisicoscan method to systematically identify risks in construction projects. This systematic approach starts with archive investigations, which identified some dozens of historical flows in this case. A geological analysis of locations and events showed that the cause of the instabilities has to be sought in the behaviour of the widespread presence of a fine sand layer containing Spisula molluscs.

To predict the soil behaviour in the presence of dynamic loads during construction, knowledge was developed about the
mechanisms involved in flow slides. That involved an evaluation of the execution techniques for the various parts of the project. With the introduction of additional measures, it emerged that construction using the usual foundation techniques was possible without damaging the existing sluices or the flood defences. This represents a considerable cost reduction by comparison with the low-vibration approaches that had previously been thought necessary.

The narrow fit for the new sluice will mean that there will be very little room on one side of ships coming in from the sea. To ensure safe manoeuvres, this factor was extensively studied under Deltares management using scale tests in the Hydraulic Laboratory in Borgerhout (Antwerp) and real-time simulations at MARIN in Wageningen, which included the hydrodynamic interaction between the ship and the immediate surroundings (the sluice and the asymmetrical outer harbour). This research enhanced our understanding of the minimal space between the ship and the nearby southern bank of the outer harbour at the point where the ship sails into the sluice inlet.

A second important factor in the operation is level adjustment. Although the difference between the levels on either side of the sluice is small, the difference in density (associated with fresh and salt water) can result in considerable forces being exerted on the ships.
The ExoMars Rover will undertake geochemical, exobiological and other research on the red planet. The vehicle will have to traverse various kinds of terrain – sand, rock and dust – and remain in motion throughout the entire mission. What demands will this make on the wheels? Low energy consumption is an important requirement: a few metres of solar panel must be enough to power not just the vehicle’s movement and experiments, but also communications with the home planet.

ESA has called on Deltares to assist. Conditions on Mars are difficult to reproduce in the laboratory, but Deltares was able to draw on our knowledge of soil mechanics to model the wheel-soil interaction. Both the finite element modelling exercise using Abaqus and the wheel parametric module (WPM) came to grips with the physical phenomena and produced results that are a fair match with the experimental data from our Zürich-based partner RUAG.

The results of this research have potential terrestrial applications, for example in the design of tractors, excavators, dredgers and soil drills, or in the processing industry, where granular materials have to be stored, mixed and transported as part of production processes.

Starting with triaxial cell tests on two Mars-like soils and stress conditions, the simulation in these cell tests generated suitable parameters for the finite element modelling of the soil-wheel tests using the Drucker-Prager Cap Hardening soil model. The computation effort required is an important component of the limitations imposed by numerical procedures. Here, an optimal
balance had to be struck between the reduction of the complexity incorporated in the simulation and the production of realistic results, necessary for validation of the modelling against the experimental results.

The soil behaviour in traditional models is determined on the basis of simple empirical field experiments and not on geotechnical laboratory testing (triaxial, biaxial or DSS testing). This implies that the traditional empirical practice for the tractive performance of wheels on soil is not embedded in geomechanics. The purpose of the wheel parametric module (WPM) modelling was to narrow this gap, and to incorporate more realistic soil behaviour in the WPM. We have not looked at normal and shear stress distributions (which cannot be verified) but only at the integrated stresses over the rim of the wheel. This reduces a number of uncertain parameters and creates a more robust model in mechanical terms that is based on equilibrium conditions for forces and torque acting on the wheel, both for the rigid and the flexible wheels being considered by ESA. In the end, under imposed slip values, the WPM produces results for drawbar pull, torque, and sinkage. In essence, the model captures the features of the wheel-soil interaction. This has been shown in the application of the model to rigid and flexible wheels with the two Mars-like soils and different loadings. In general, the torque is captured very accurately. The estimates of drawbar pull and sinkage are also estimated quite well.
scope

The subsurface, the geotechnical and soil environmental quality, and groundwater and surface water systems are literally the foundation of sustainable life in the delta. Our understanding of this physical system must be properly folded into spatial planning processes by contributing the relevant information at the right time and in the proper way. The major impact of Deltares here is made up by supporting policy making by uniting the human sciences with technical disciplines.

background

Structuring and planning help to safeguard the sustainable use of space in deltas. The basic assumption for Deltares is that the geo-ecosystem determines use options and quality in the long term and therefore that it provides the direction for spatial design and structuring. An important precondition for sustainable structuring is a match between the design and the dynamics of the system. In addition, society’s requirements are not static. The system diagram for Spatial Development provides an overview of the relevant factors.

The opportunities and limitations of the physical system, as well as social requirements, play an important role and they are shown as the inputs for the system. At the top, we see the support and direction that Deltares can provide in this process, such as risk analysis, assessment frameworks, appraisal instruments and reviews. The outcomes of interest on the right include climate robustness, sustainable use and spatial quality. These three outcomes constitute three perspectives that can be used
as frameworks for the assessment of spatial structuring (such as spatial design and planning) and they complement each other.

The subjects of the four programmes in this theme are *Climate, water and spatial planning, Concepts, methods and instruments for spatial planning, Sustainable delta cities* and *Delta Governance.*
The aim of the European FP7 project FloodProBE (Flood Protection for the Built Environment) is to learn more about flood resilience and flood protection performance in order to balance investments in flood risk management in urban areas. To this end, technologies, methods and tools for flood risk assessment and for the adaptation of new and existing buildings and critical infrastructures have been developed, tested and disseminated.

Knowledge supporting flood risk management has advanced significantly over the past decade. Experience has shown that much of the knowledge developed during research projects does not become effectively available for policy and other stakeholders due to a range of underlying factors. FloodProBE therefore paid special attention to making the newly developed knowledge available for policymakers and other stakeholders. One of its work packages was specifically initiated to achieve this goal by integrating knowledge in decision-support processes, bringing together knowledge and stakeholders through pilot studies and making the knowledge easily available to a larger public.

The general framework describing the decision-making process in flood risk management as developed in the FLOODsite project served as a basis for mapping out the different types of policy issues. The general framework consists of three main elements: risk assessment, the identification of possible responses, and balancing risks and responses.

An initial activity involved taking a closer look at decision-support systems (DSS) in particular. A DSS allows strategic alternatives for flood risk or flood event management to be defined and analysed, and can rapidly calculate the effects of these alternatives. The main aim of these systems is to
help decision-making processes in a policy context. As well as providing an overview of the DSSs currently available, the analysis also showed the range of policy issues being addressed by the DSSs. Five main policy issues were identified:

- Maintenance planning
- Flood risk assessment
- Insight into possible solutions
- Balancing problems and solutions
- Establishing support for, and awareness of, flood risk management plans

Bringing research and policy together is referred to as Science Policy Interfacing. By tackling Science Policy Interface (SPI) barriers, for example by improving communications with stakeholders or improving the form of reports, the project researchers aimed to enhance the use and application of their products. An initial step in tackling SPI barriers involved establishing an understanding of the general barriers encountered in the Flood Risk Management community and developing solutions and recommendations for improving the SPI within EU research projects. This was done through the FLOODrisk2012 conference and a policy paper with suggestions for ways of overcoming SPI barriers. Recommendations included implementing the role of a knowledge broker and planning for a cascaded form of communications, with material being specifically formatted for different user communities.

Further reading
Humans have always been more interested in their visible surroundings - such as the landscape, air and water - rather than in the subsurface. The public, including many intellectuals and policymakers, generally have no idea about the subsurface, let alone the processes that govern it and how these may determine our lives.

The urban environment results in a significant claim on space as well as resources (water, food, energy and materials) that are linked to the subsurface and that allow present-day society to function. The subsurface has many roles and uses.

One of the main trends in the spatial planning of the urban environment has been increasing urban density. The literature describes a number of negative impacts associated with current urbanisation practices, such as the direct loss and fragmentation of natural habitats, the creation of urban heat islands, air pollution, water contamination, and exotic species introduced by humans.

As we are running short of affordable and sustainable options for an expanding (and increasingly urban) human population, the subsurface may provide a last and challenging resort to future generations. Multiple use of space by stacking functions in the subsurface could increase urban density with fewer negative effects than the current options on the surface. However, there is a need to decide about the proper balance between exploitation and protection, and therefore to arrive at informed decisions about the sustainable development of the subsurface in the urban environment.
The development of a framework for the sustainable development of the shallow subsurface is the focus of an ongoing doctorate study. The main research question relates to the prevention of urban sprawl and increasing urban density as well as improving the quality of life in the urban environment. Not only should this take earth sciences and geotechnical sciences into account; it should also look at the legal and socio-economic aspects of these developments to identify viable options.

Several elements will contribute to the framework under development. The spatial planning process may benefit from the application of Spatial Multi-Criteria Analyses (SMCA) as a tool to derive a subsurface opportunity indicator. Resource- and energy-efficiency in subsurface development are supported by Life Cycle Assessment, which also include the subsurface impacts of developments on the surface. Public acceptance may be enhanced by introducing a subsurface lease model to balance local impacts and regional/national benefits. A proposal for a subsurface lease model encompasses a trading mechanism in which all stakeholders participate based on ownership and legal responsibilities via the surface footprint of the underground development. Private landowners receive a payment for allowing subsurface developments thus potentially increasing the willingness to accept.

Further reading
The Implementation Canvas is a simple, easy to use tool for civil servants (in local government and water management authorities) that supports the implementation of long- and short-term strategies and policies. The canvas integrates the perspectives of companies, scientists and governments in one single tool. This entrepreneurial tool can be used to support a multi-stakeholder dialogue about critical issues relating to implementation, and to design and compare strategies.

The development of the Implementation Canvas was inspired by the business model generation canvas (BMGC). The BMGC is used to develop business models by optimising the nine most important building blocks of a business model. The Implementation Canvas works on similar lines to identify the principal building blocks for the implementation of measures in the public domain.

The canvas was originally developed to understand the critical issues relating to the implementation of climate adaptation measures and to help stakeholders to face those challenges. One of the challenges the canvas addresses is the cross-sectoral nature of adaptation measures. The disciplines involved range from climate expertise and impact assessment to policy formulation, water management, spatial planning and the actual design of infrastructure and construction, and to cost and benefit analysis.
The implementation strategy is being designed and optimised by discussing each of the building blocks in the canvas. This can be done by a single stakeholder designing his own strategy, or by a group of stakeholders developing a shared strategy. The Implementation Canvas consists of multiple layers. The top layer provides a general overview of the interrelations between the building blocks. Behind each building block, there is a new layer focusing in more detail on that specific building block and providing insight into relevant knowledge. Creating and comparing multiple strategies makes it possible to design the best suitable implementation strategy. The Implementation Canvas structures this process.

The advantage of the Implementation Canvas is that it quickly delivers an integral view of the critical issues in different implementation strategies and therefore integrates the technical issues with the governance issues. The canvas will be optimised continuously using an active international community of practice.
In a pilot project looking at how the subsurface can contribute to sustainable development, Deltares is investigating ways of transforming the IJssel - Vecht delta in the Netherlands into a climate-proof, and attractive area to work and live in. As a result of climate change, the flood risk for the IJssel and Vecht rivers will increase, and both pluvial flooding incidents and hot and dry periods will occur more frequently. Using the ecosystem services of the subsurface is one way of contributing to climate proofing that also safeguards the conditions needed to preserve the ecosystem for the future. Ecosystem services that can be used are the storage of excess rainwater, water supply during dry periods, the cooling of water in the summer season and the cleaning of water.

The project is guided by the Delta Principles, a set of rules of thumb for a sustainable water and subsurface system, and the way they can contribute to a delta that is attractive to work and live in. These principles bring together complex overall Deltares knowledge in simple rules with the aim of looking at what can be done to work towards a sustainable water and subsurface system. These rules of thumb have been translated to the local context and used to identify possible measures for specific sites. In this way, the Delta principles contribute to shaping the sustainable development of an area.

Co-creation is at the heart of this project. Measures are appraised in collaboration with stakeholders, who are invited
to cooperate in the transition process and encouraged to develop initiatives of their own. Small-scale experiments by stakeholders are supported, allowing them to establish a clearer picture of further possibilities. Adopting a controlled approach to this activity means there are few risks.

The project comprises three phases. In the first, we carried out a system analysis and generated a long list of measures based on the Delta Principles. In the second, which is now under construction, we are initiating the co-creation process with local stakeholders and developing business cases. We are investigating the business case of a new drinking water source, and this also serves as a water management tool at the same time. Another concept which is being investigated is ‘closing the urban water cycle’: in dry, warm seasons the entire urban surface water system is linked to a single cycle. It is coupled to the deep (30m) lakes around the city of Zwolle, and the cycle is led through natural biofilters (i.e. reedlands) to get excess nutrients out of the water. The system as a whole provides the city with clean and cool water.
The sustainable development of deltas requires sophisticated tools to support the planning processes in these areas. Policymakers, planners and project developers face increasingly complex challenges and future uncertainties that require a multi-disciplinary approach. The complexity of the challenges also means that many stakeholders need to be involved in the planning process to address them and come to a widely supported, joint problem definition or strategy that takes full advantage of the potential assets of an area.

The Climate Adaptation Atlas is just such an interactive tool. It opens up and visualises spatial information about the physical, socio-economic and institutional system for a wider audience. It can be used for problem analysis, awareness raising, agenda setting, joint fact-finding, capacity building and strategy development. The atlas has proven important as a tool that helps policymakers to address climate adaptation issues and formulate priorities for adaptation strategies.

Last year, the atlas was developed and applied for a case study area in Bangladesh in a project that also involved Dutch colleagues from Alterra/WUR, Geodan and Geocycli and local Bengali partners from the Center for Environmental and Geographic Information Services (CEGIS) and the Haor Water Development Board. The objectives of the project were to develop a platform for participatory planning for the Haor area in Bangladesh, to visualise scenarios for the long-term future, to apply the touch table as a platform for participatory planning and to show how the approach can work for Bangladesh and other regions in the world.
In preparation for a series of workshops focusing on the touch table, spatial information about the Hoar area was gathered and structured. The Hoar area (in the North-East of Bangladesh) accounts for a large proportion of rice production in Bangladesh, but the area is subject to high demographic pressure and devastating flash floods. Socio-economic scenarios for the long-term future (2050) were developed using a land use model (LUMOS) and drawing on regional growth numbers to project future land use claims. The possible impacts of climate change were analysed in a simple rainfall accumulation model for estimating possible future changes in the timing and frequency of flash floods. The results of these modelling efforts were discussed in the participatory workshops where the atlas was used and where the focus was on the touch table. In consultation with public stakeholders and local experts around the table, flood hazard maps and vulnerability maps were verified on the basis of local knowledge and synthesised to produce risk maps. After the joint identification of high-risk locations, the participants selected appropriate measures and placed them on top of the risk maps in a first attempt to arrive at an indicative adaptation strategy for the region.

Further reading
http://www.climateadaptationservices.com/gfx_content/documents/Bangladesh%20info%20folder%20interactive.pdf
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Design
Welmoed Jilderda

Printing
Drukkerij van Deventer bv