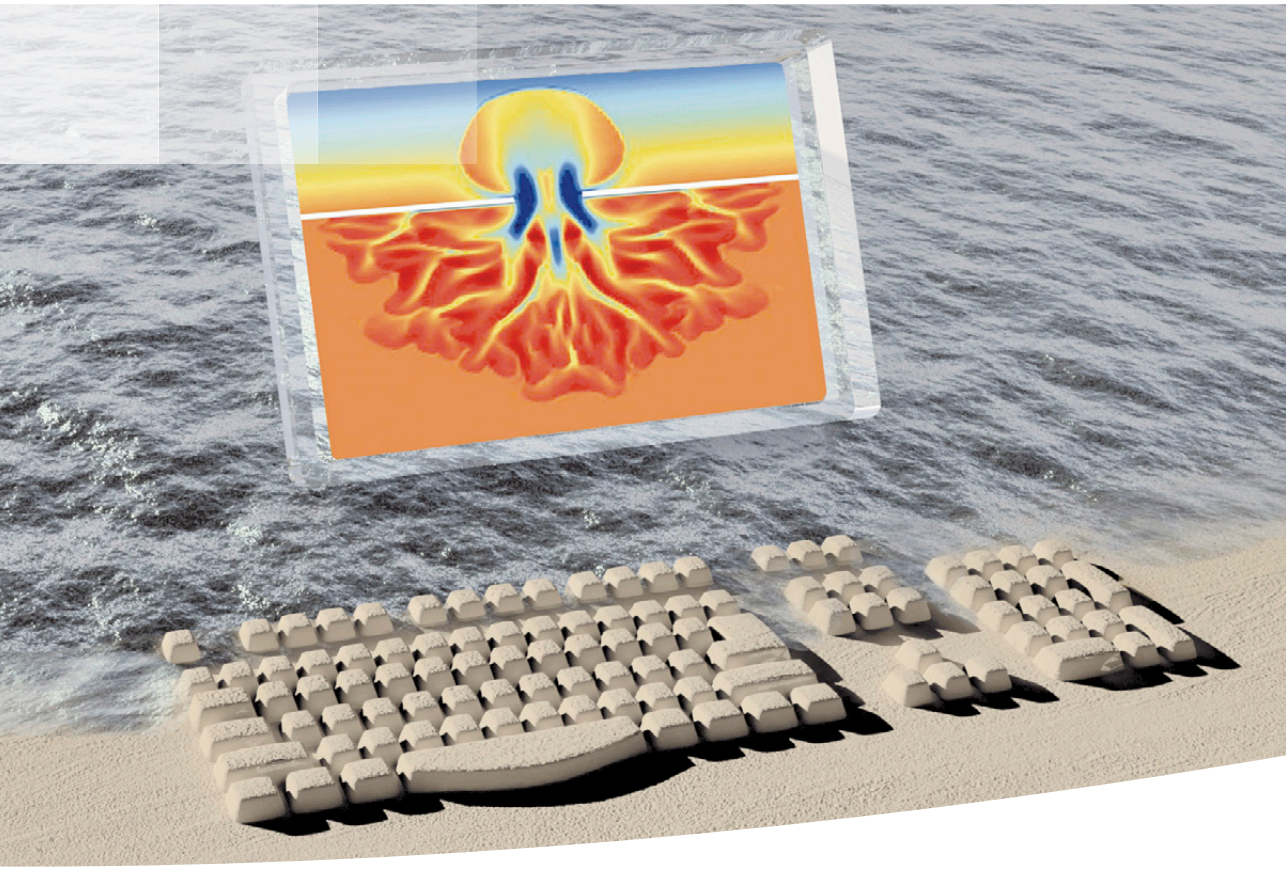
Deltares

Enabling Delta Life

R&D Highlights 2010



R&D Highlights 2010

Foreword

Dear reader,

It is my pleasure and honour to present you Deltares' research highlights of the year 2010. More than 850 Deltares-employees are involved in high-grade research and consultancy in the field of delta technology. This concerns the technology needed for sustainable living, working and recreating in low-lying, densely populated areas constituting the interface between land and sea: enabling delta life. This requires technical skills and 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. I hope this report shows that Deltares and its partners are on the way to establishing that interdisciplinary approach.

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.

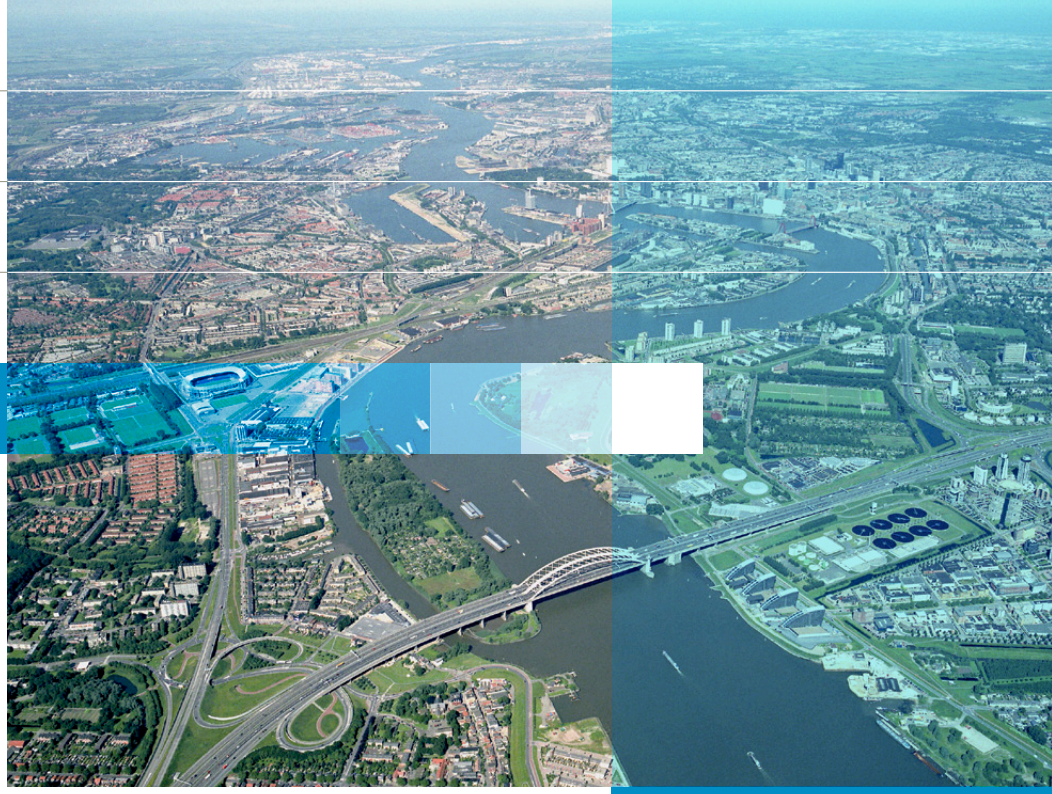
Prof. dr. Huib de Vriend
Director Science of Deltares

Contents

Deltares in the world

Deltares and its predecessors have been involved in R&D on Delta issues for more than 80 years. An important transition started in 2003 when the government found that too little fundamental research was being transformed into innovative applications that move the Dutch knowledge economy forwards.

Why wasn't more knowledge getting through to the end user? A part of the answer to this "innovation paradox" is the way the knowledge infrastructure works. It was concluded that there should be a much more direct connection between knowledge institutes and the corporate sector, and that the latter needed to be encouraged to use new knowledge.



The 2010 R&D Annual Report

One of the Deltares aims following on from this "connection" between the public and private sectors is to make R&D results more accessible. All roads lead to Rome, and we have numerous resources at our disposal for disseminating this knowledge: scientific publications, technical publications, reports, the website, wikis, communities of practice, courses and software.

This R&D Highlights report for 2010 presents a selection of the R&D conducted in 2010 and it is structured on the lines of the social issues that are central to the Deltares mission. To enhance interactivity, one or more contact persons are listed for each project. People interested in more details should approach them.

A PDF version of these R&D Highlights 2010 can be downloaded from www.deltares.nl

R&D policy and issues

Demand-driven

In the policy memorandum "Kennis voor de Samenleving" (Knowledge for Society, 2005), the government emphasises the need for a process of demand programming and financing for applied research at the Dutch knowledge institutes like Deltares. Demand programming ensures that there is more focus and quality in the research programmes. It results in a closer match between this research and strategic questions from government, the corporate sector and civil society. This is important to alleviate the innovation paradox and to enhance scientific research for society in general.

In the course of elaborating this ambition, the government gave strategic themes and social and innovation challenges a leading role in the research programmes. This focus on strategic themes should also extend the knowledge networks of the knowledge institutes, both at home and abroad. In this process the responsible ministries, in collaboration with the corporate sector, civil society and knowledge institutes, formulate the research issues within the parameters of the strategic themes.
The research programmes are adapted accordingly and the government financing is linked to these research programmes. In 2006, the government formulated a number of strategic themes, including the associated social challenges or sub-themes, focusing expressly on the development of the technology and knowledge positions of the knowledge institutes, both within and across the themes.

In the new approach, the government directs the process of demand programming. The basic principle is that the process takes place interactively, with the demand side and financiers determining the knowledge and research issues. The issues are formulated in "knowledge arenas" that include the relevant stakeholders from the demand and supply sides. These arenas act as dynamic networks for an open innovation process. The corporate sector has a clear role in the process of demand programming. The government asks the corporate sector to participate actively in the knowledge arenas and, in that way, to make a contribution to steering the applied research financed by the government.

In order to secure the demand programming, the Ministry of Transport, Public Works and Water Management established a Council for Delta Research (Raad voor het Deltaonderzoek, RDO) with members from the government, knowledge institutes and the private sector. The council has defined the strategic knowledge and innovation issues with respect to water and subsoil in her Strategic Document (2009). The issues have been allocated to five themes:

- **Safety** - Living safely in the delta
- **Healthy water and soil systems** – Areas with quality
- **Availability of water and soil systems** - Scarce resources
- **Living and building in the delta** - Lack of space
- **Integrated spatial development**

The Deltares R&D programme has been organised along the lines of these five themes. The themes have been broken down further into research lines known as "road maps".

Mind maps for total R&D 2011, theme Living and Building in the Delta, and road map Offshore developments

Road maps

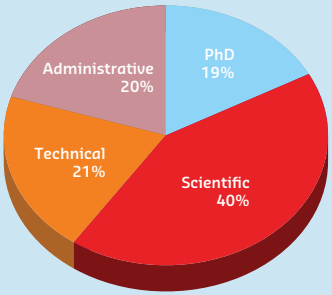
The strategic social themes and issues in the themes are elaborated using what we call "road maps". We see these road maps as the vehicles for the communications relating to our strategic knowledge and innovation lines. They are, by definition, temporary and they are constantly under revision. The formulation of road maps, including fundamental, strategic and applied components, represents a considerable challenge since communications must introduce focus, clarity and simplicity to an inherently complex collection of information.

The entire research plan is visualised in the form of mind maps: theme charts for each theme and, at a more detailed level, road map charts for each road map.
The theme charts describe the broad outlines of Deltares research. The charts show, for example, the countries where Deltares is active for a theme, the theme-relevant trends and the theme returns. The road map charts associated with the theme describe the research in more concrete terms. These charts cover elements such as the social issues addressed by the road map, the planned products, the purchasers of those products and the road map resources. The road map charts also describe the research lines. Broadly speaking, each research line is in one of the following phases: development, realisation or application. Individual projects in the road map may be in different phases; the designation of a phase provides a broad visual indication of the status of the research.

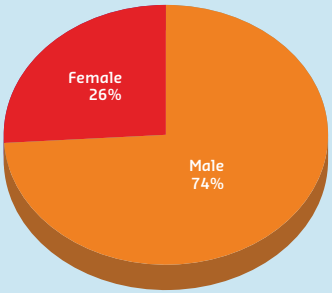
Facts and figures

Deltares brings knowledge about subsurface, soil and water systems together under a single roof. We use this knowledge in our own deltas and abroad. Translating science into solutions for delta-related issues is the core of the Deltares activities.

The yearly turnover of Deltares is about 110 M€, half of which is generated by R&D.
The activities range from short- and long-term projects to targeted research, and include multidisciplinary policy and management studies. Deltares is also known for its unique experimental facilities and its powerful software, most of which is developed and validated in-house.



Number of employees 875
(800 full time equivalent)



Male/female ratio Deltares employees

Advisory Council

To advise the management about the research programme and the strategic positioning of the research, Deltares established an external advisory council with representatives from the knowledge world and from the commercial sector. The issues dealt with by the advisory council are of a long-term nature. They include the question of where Deltares should invest to continue to fulfil its role, and which knowledge issues should be addressed in order to produce answers a few years hence.

The members of the advisory council are:

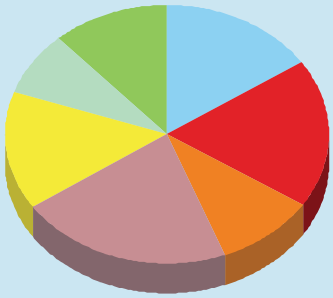
- **Professor Jacob Fokkema** (chairman), Delft University of Technology
- **Piet Besselink MSc**, DHV Holding BV
- **Professor Rietje van Dam-Mieras**, Leiden University
- **Professor Aad van der Horst**, Delta Marine Consultants
- **Cees Slingerland MSc**, Environmental Sciences Group, Wageningen University and Research Centre
- **Arnold Steenbakker MSc**, Fugro N.V.
- **Professor Marcel Stive**, Delft University of Technology
- **Professor Bert van der Zwaan**, Utrecht University

Knowledge Centre

By implementing demand-driven programmes, Deltares invests in knowledge and technology in the area of water and the subsurface. The basis and the source for answers to knowledge issues is disciplinary knowledge. This basis must be maintained at an international standard. Together with universities, Deltares is investing in fundamental strategic research and networks of contacts in delta-technology disciplines.

Deltares focuses on water and the subsurface as systems, on measuring them, on civil engineering, and on human sciences. A large number of disciplines and sub-disciplines are relevant for the Deltares field of activities. The employees of Deltares, with their personal commitment to their own field of expertise, support the disciplinary framework. Deltares facilitates disciplinary activities in an organisational structure of seven disciplinary clusters, each of them co-chaired by a member of the scientific board and one of the Deltares research theme managers.

- System informatics
  - *measuring and monitoring*
  - *mathematics and information technology*
- Environmental sciences and engineering
  - *chemistry and microbiology*
  - *ecology*
  - *eco-engineering*
- Geosciences and engineering
  - *soil mechanics and soil construction*
  - *geology*
- Hydro- and morphodynamics
  - *hydrodynamics*
  - *sediment transport and morphology*



Employees according to primary expertise

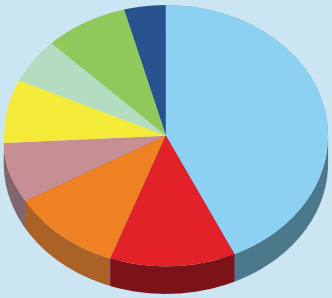
88	System Informatics
105	Environmental sciences and engineering
58	Geo sciences and engineering
120	Hydro- and morphodynamics
84	Hydrological sciences
46	Hydraulic and geo-engineering
66	Social sciences and policy analysis

- Hydrological sciences
  - *hydrology*
  - *geohydrology*
- Hydraulic and geo-engineering
  - *foundation technology and underground construction*
  - *hydro-engineering*
- Social sciences and policy analysis
  - *risk management*
  - *spatial sciences*
  - *life sciences and social sciences.*

Cooperation with the universities is established through chairs and other appointments, and joint R&D projects conducted by PhD students. About 75 doctorate students are acquainted with Deltares in some way, as are 14 part-time professors and 14 university teachers. Six doctorate students completed their dissertations in 2010.

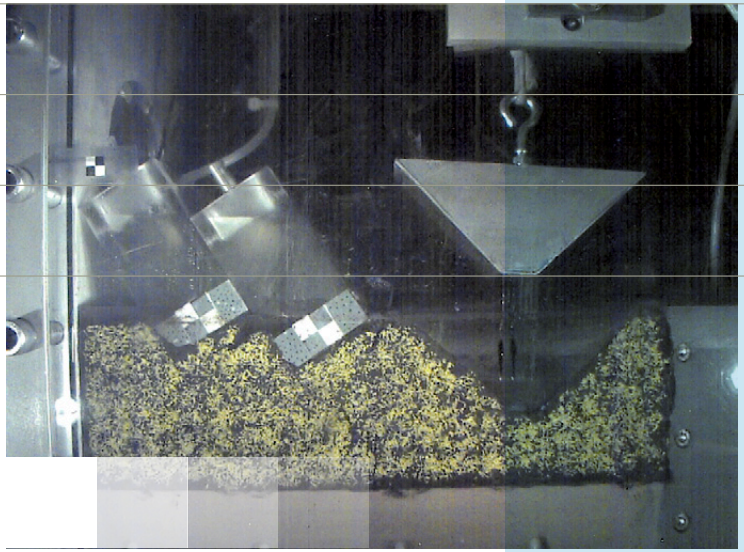
Deltares works with universities to invest in knowledge centres at the universities of Delft, Utrecht, Twente and Wageningen. Current examples are the Geo-Engineering Knowledge Centre at Delft University of Technology, the Risk Management Knowledge Centre in conjunction with the University of Twente, the GeoSciences Knowledge Centre with Utrecht University and the Ground Knowledge Centre with Utrecht University and the Wageningen University and Research Centre.

In 2010 four of the discipline clusters have been audited by an international committee. The committee concluded that several of the clusters are internationally recognised jewels or have the capacity to be so, especially when seeking collaboration with TNO and Delft University of Technology.



PhD-students by university

27	Delft University of Technology
13	Utrecht University
9	Twente University
7	Wageningen University and Research Center (WUR)
5	VU University Amsterdam
4	Unesco-IHE
7	Other (Netherlands)
3	Other (Abroad)



Geocentrifuge test IJkdijk

Scientific Board

The Scientific Board plays an important role in terms of the function of Deltares as a knowledge centre. This Board consists of ten Deltares members of staff with international reputations who monitor the quality of the knowledge activities at Deltares and provide the management with advice – both upon request and at the Board's own initiative – about the research programme, strategic investments, the discipline groups and the relationships with the universities. The members of the Scientific Board are:

- Professor Frans Barends
- Professor Eelco van Beek
- Professor Marc Bierkens
- Professor Remi Laane
- Professor Arthur Mynett
- Professor Huub Rijnaarts
- Professor Dano Roelvink
- Professor Frits van Tol
- Dr. Rob Uittenbogaard
- Professor Huib de Vriend

Facilities

The ability to break down natural processes into basic processes using a system approach, and to conduct relevant experiments, is needed if we are to meet demands for greater accuracy and reliability from society as a whole.
So Deltares cannot fulfil its role as a knowledge institute without "cutting-edge" facilities. These facilities are: physical modelling installations, test sites in the field and numerical model systems. The research programme allocates budgets for research at and with these facilities.

GeoLab clusters facilities and expertise for research into soil and soil-related materials: laboratories for the advanced measurement of soil parameters, data-handling tools and model-research facilities. The GeoCentrifuge is one of the largest geotechnical centrifuges in the world specialising in soft soils. These facilities are mainly used in the road maps of the themes "Living and building in the delta" and "Safety: living safely in the delta".

HydroLab includes a cluster of facilities for research into water-related topics. The model research takes place in three halls (the saltwater/freshwater facility, the channels facility and the currents facility) and the Delta Flume. These hydraulic laboratories are used in the road maps in the core domains "Safety: living safely in the delta ", "Availability of water and soil systems " and "Living and building in the delta". In 2009 a grant was awarded for a complete renewal of the Hydrolab facilities, culminating in a new Delta Flume at the Deltares premises in Delft.

Delta Flume

Instrumentation at field lab

MilieuLab includes a cluster of facilities for research into hydrochemistry-, geochemistry- and microbiology-related processes that are important for delta areas. The environmental facilities in Utrecht are shared with the University in Utrecht and TNO. These facilities are used in the road maps in the theme "Healthy water and soil systems".

Field labs

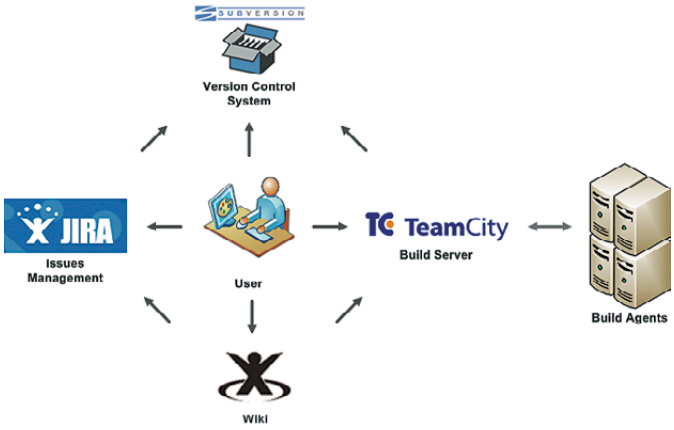
Measurements in the field are, ultimately, the "proof of the pudding" for predictive calculations. Field laboratories are of pre-eminent importance in this respect and they are therefore the second cornerstone of the innovation triangle. The work here involves physical soil and water experiments monitored using geophysical measuring equipment in the field. Examples include experiments in dikes (the Smart Dike and the Live Dike), on the coast (Ecobeach), in surface water (Vlietlanden) and the sea (Eastern Scheldt). There are also chemical and microbiological experiments in the field such as the encouragement of natural degradation processes at various remediation locations and experiments with SmartSoils innovations (strengthening dikes, sealing underground leaks).

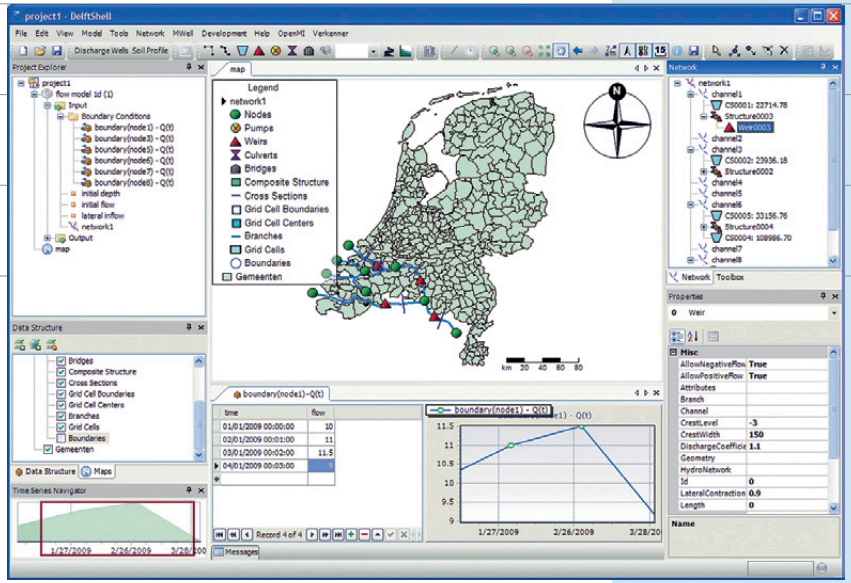
ICT facilities

The third component of the facilities consists of the software development platforms with a shared architecture. This facility is vital for the development of new dynamic modelling methods and as a basis for a large number of applications. Software plays a key role in the dissemination of the very latest knowledge to a wide range of users.

The ***Geosoftware Platform*** is used for the development of functionality in geomechanical and geotechnical software (in the well-known M series). ***The Hydrosoftware Platform*** is used for the development of hydrological, geohydrological and hydraulic software: Delft3D, Sobek, Modflow. ***The Environmental Software Platform*** is the place where we develop Delwaq.

New knowledge acquired during disciplinary research and in various road maps is transformed as much as possible into new functionality for software on the platforms.





DeltaBrain, finally, combines a range of knowledge sources in the shape of expertise (data, models) with knowledge based on experience. The unique combination of "hard" (objective) measurements and computer models and "soft" (subjective) experience and expert knowledge makes, with adaptations for particular applications, a contribution to risk management and decision support for delta issues. It constitutes the virtual and life-long learning and working environment for present and future generations of delta engineers. GeoBrain is the part of DeltaBrain that focuses on geo-engineering and there is already a range of applications here.

Water, subsoil and spatial development

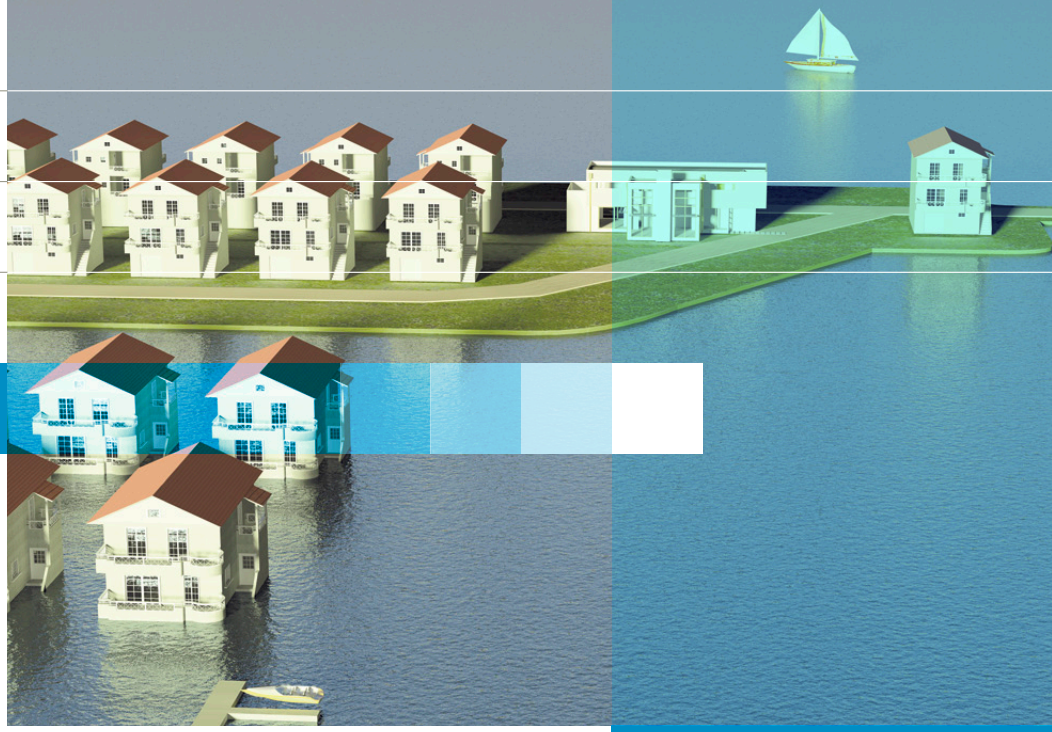
scope

The subsurface, 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. Here, the human sciences are crucial rather than technical disciplines.

background

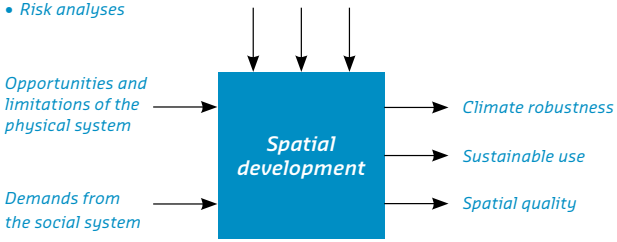
Structuring and planning help to safeguard the sustainable use of space in deltas. The basic assumption for Deltares is that the geo-ecosystem determines use options and quality in the long term and therefore that it provides the direction for spatial design and structuring. An important precondition 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 input for the system. At the top, we see the support and direction that Deltares can provide in this process, such as risk analysis, assessment methods and instruments, valuation instruments and scenario studies. 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



Deltares makes knowledge available in the form of products that can support this process:

- *Valuation tools*
- *Assessment methods and tools*
- *Scenario studies*
- *Risk analyses*



complement each other. They are at the root of the three road maps in this theme.

The road maps in this theme are *Climate adaptation, water and spatial planning, Research by design and spatial quality, Methods and instruments for spatial development processes and Marine* and *land spatial plannig*

Contact

rosalie.franssen@deltares.nl
+31 (0)88 335 78 18

ireen.roling@rws.nl

Temporary Use of Land

Strategy for adaptive land use management

Everything changes, everything is temporary! In spatial development, we now design for eternity, with a little flexibility in the functions. But how final is a plan 30 years on? The concept of the provisional use of land requires a transition: another way of thinking, designing and financing that also involves new revenue models.

Temporary Use of Land is a new spatial concept, with flexibility in time and space at the centre. It can be used in areas characterised by changing functions, high dynamics and climate adaptation, and in areas in transition. The concept makes an area profitable, while keeping it available in the longer term for future - often uncertain - functions.

Ooijen-Wannsum Case

Ooijen and Wanssum are communities located on the River Meuse. Plans are being developed for this river to reduce the probability of river floods in the long term. Water will be allowed back into designated areas. The plans include a secondary channel for the River Meuse. From 2050 onwards, the land will have to be available for water storage. The current Water Act prohibits other developments from now on, despite the long time horizon of the plans. Within the area concerned, there are several small-scale plans and initiatives for temporary housing and recreation. However, they cannot be executed due to the legal restrictions. In the different phases of the project, land that is available for a limited time only can house provisional functions or activities. Mapping the potential for provisional functions in the area unlocks the current planning paradigm and makes the area active.

FloatingLife Case

FloatingLife is an experiment in spatial development. Since 2010, it has been serving as a demonstration of the sustainable floating city, with floating buildings housing exhibitions, conferences and debates. It is a laboratory for flexible and provisional spatial development. FloatingLife is located in Pampushaven, a small harbour near the city of Almere. FloatingLife is an example of how to exploit the space left by current legislation for Temporary Use. The possibilities that have been identified have been collected in a legislative overview. Furthermore, sketches were made for temporary utilities and economic feasibility was also studied.

The Netherlands has a strong international reputation in the interface of water and spatial development. Space for innovation and application is important if the country is to maintain its position at the forefront. The coordination of sustainability, flexible developments and provisional functions opens up an opportunity to connect to current and urgent developments both in the Netherlands and other countries.

Partners

- Corporate Innovation Program Rijkswaterstaat
- InnovatieNetwerk
- CUR.net
- Dura Vermeer

Further reading

www.tijdelijkandersbestemmen.nl

Images: D.efac.to architectuur

Contact

marjolijn.haasnoot@deltares.nl
+31 (0)88 335 81 75

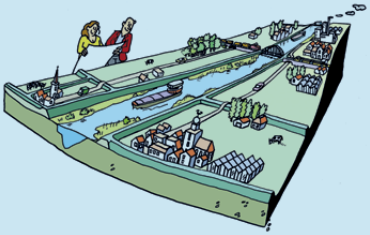
eelco.vanbeek@deltares.nl
+31 (0)88 335 84 19

Sustainable Delta
a serious game for exploring pathways

Sustainable water management can cope with uncertainties in the natural and social environments. Ideally, a strategy will be robust when climate change scenarios, socio-economic developments and societal perspectives change, or the strategy will be flexible enough to adapt. Uncertainties inherent to these developments lead to different potential pathways for water management as we move into the future. The main purpose of this project is to develop a method for identifying sustainable adaptation strategies in river deltas given the uncertainties about the future. The approach includes the response in terms of water management and society.

To explore adaptation pathways for many integrated transient scenarios, a conceptual framework describing the water system-society interaction, and an Integrated Assessment Meta Model (IAMM) were developed. These can be applied in a game setting in which players of the game take on the role of water managers and respond to events and developments in the water-society system in specific realisations of a climate scenario. Responses include the choice of specific river management options, changing perspectives and dynamics in advocacy coalitions of players.

In the game, the water system is modelled with the IAMM, the socio-economic scenarios are presented in the form of newspaper headlines, and the climate change scenarios appear as realisations of a weather generator and a hydrological rainfall-runoff model. The IAMM allows for a rapid calculation of how climate change and socio-economic forcing may lead to changes in river hydrology, land use, and impacts on various river functions. This game format was applied to a "virtual case" involving a virtual river stretch representative of many river stretches in the Netherlands. The situation of the Waas was inspired by a low-lying river stretch in the Rhine delta of the Netherlands.



Before each gaming session, a specific realisation is chosen by the project team. Realisations may be selected on the basis of the timing and frequency of discharge peaks and the extent of climate change, depending on the type of responses the project team aims to assess. In each session, the participants will be confronted with a year-by-year evolvement of river runoff, related impacts on safety, damage, shipping and ecology, and changes and events in society as a whole. An adaptation pathway is completed when the participants have managed the river for 100 years.

The game makes it possible to see the importance of interactions between water systems and society. It can help to establish an understanding of possible responses in different circumstances and to develop ideas about how to draw on this in the development of water management strategies.

Further reading

http://perspectivesiniwrm.deltares.nl

Partners

- ICIS-University Maastricht
- Utrecht University
- Twente University
- KNMI
- Pantopicon and Carthago Consultancy.

Contact

oswald.lagendijk@deltares.nl
+31 (0)6 51 78 96 65

Connecting knowledge through research-by-design

Not seldom, despite the high quality of the research, scientific reports prove difficult to implement in the daily practice of policymakers and planners. The effect is a suboptimal result or a suboptimal evaluation. Accordingly, new, innovative ways are being sought to improve the ways this knowledge about water, soil and subsoil systems is included in planning and policy processes.

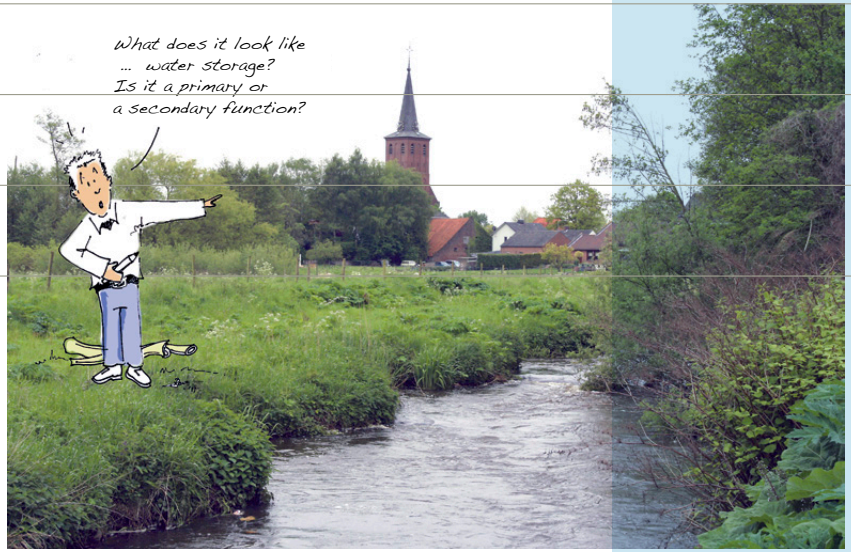
Dordrecht

www.flickr.com/hetty51

In the search for ways of improving the application of scientific resources and capital, a link has been made to the world of designers, architects and landscape architects. This began in 2009 with a collaboration with the Graduate School of Design of Harvard University. At the request of the Dutch Ministry of Transport, Public Works and Water Management, two Dutch cases were brought forward looking at climate change, land development, water and adaptation: the Almere upscaling strategy and the City of Dordrecht, squeezed by possibility of riverine flooding and sea-level rise.

About 30 students (graduates of architecture, urban planning and landscape architecture) engaged in three months of research-by-design that resulted in challenging concepts for combining city growth and economic development with climate changes like sea-level rise and higher temperatures.

What has been learnt from these exercises? First of all, you cannot look at a climate issue like water safety solely from the point of view of water and water-related disciplines. In the words of Harvard



professor Pierre Belanger: "The water safety issue in the Netherlands is primarily a spatial issue."

Secondly, by combining technical, specialised expertise and designer qualities, new perspectives can emerge in a relative short time, both in the area of problem definition and in the area of problem-solving and solutions.

Thirdly, this research-by-design method should be adopted more frequently by knowledge institutes such as Deltares, which will then draw more on the qualities of designers and architects, as they can contribute to an integrated approach in context and content.

The Harvard lessons have been put into practice in different settings, in particular in the Dutch Delta Programme. In cooperation with designers from the Dutch Government Service for Land and Water Management, a series of "Water Studios" or "charrettes" were organised in the cities of Zwolle and Bergen op Zoom and on the island of Goeree-Overflakkee. In a very short time frame of a few days, a lot of expertise was brought together and focused successfully on elaborating short-term 'action perspectives' for long-term climate changes.

Partners
Graduate School of Design
of Harvard University

Contact

pim.witlox@deltares.nl
+31 (0) 88 335 76 31

Visualisation prototypes

The aim of the visualisation project is to establish innovative visualisation and control techniques. Three software applications have been developed in the past few years: "MapTable", "Building Excavation Game" and "Sand Motor". These applications were developed for use on touch-based interfaces and have been tested on the Microsoft Surface Table. One of the main reasons for this development was the emergence of touch-based devices such as the iPad and Android Smart Phones. This development lowers the user threshold for these types of applications and gives Deltares the opportunity to investigate the benefit of new technologies for application to Delta issues.

The MapTable is software that is primarily used to make decisions in the "room for the river" project. With climate change, the Netherlands will need to cope with more water entering the country through the Rhine and Meuse rivers. The MapTable design software based on GIS data can read an existing situation, after which a group of people can make adjustments and then see how the changes affect the environment and urban landscape, and the changes in the water flow. A 3D projection based on the changes is displayed on a secondary screen. Consulting firm Arcadis has been working with this software for a number of years now to support policy development processes. A good example of this is the Arnhem-Nijmegen focus area.

Around the pit

The Building Pit Excavation Game is a "serious game". A serious game is a game designed for education, scientific exploration or emergency management. The Building Pit Excavation Game is a pilot study to show people what processes are involved in creating a building site. As the players walk through a scenario, they quickly learn what steps are taken and why. The prototype was designed to show the benefits of working with several people around a single touch screen. A follow-up for this software is a 3D version of the application ("In the pit") which is being developed with the Dutch consulting firm Geodan focusing on the environmental aspects of a building pit.

The Sand Motor prototype is an application that is being developed for the "Building with Nature" project. The aim of this application is to model sand replenishment off the Dutch coast. The prototype has been designed to show different methods for accessing and modifying information, and it has both a web-based interface and a touch-based interface using the same, shared components. The web-based interface was developed for more complex aggregated information retrieval; the touch-based interface was developed for less detailed, more intuitive, information retrieval.

Sand Motor

Partners

- Arcadis
- Geodan
- Building with Nature

Safety
living safely in the delta

scope

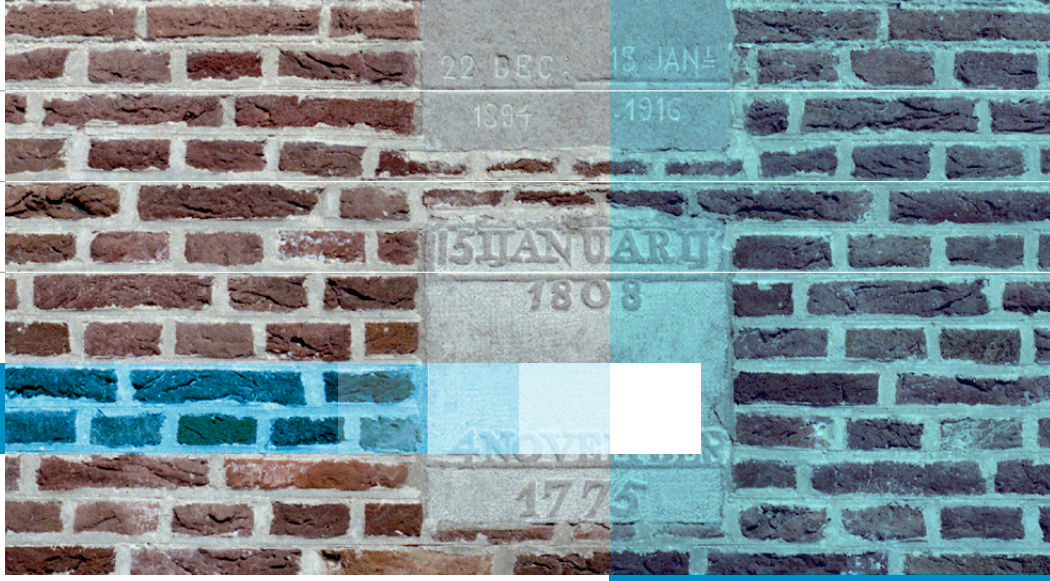
The low altitude of the Netherlands means that protection against flooding is a permanent concern. Soil subsidence and climate change are exacerbating the problem. In addition, we are making more and more demands on the spatial quality of the country. Smart dikes, improvements in our understanding of 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 heart of the research programme.

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.

The road maps in this theme are *Handling flood risks, Operational flood risk management, Coastal systems behaviour, System tools for preparation and prevention* and *Innovative design concepts for water defences*.

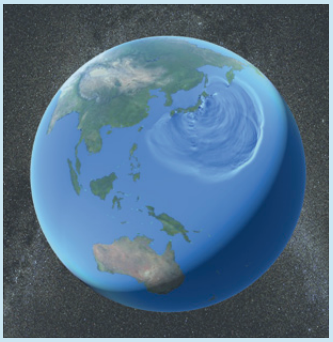
Contact

maarten.vanormondt@deltares.nl
+31 (0)88 335 82 04

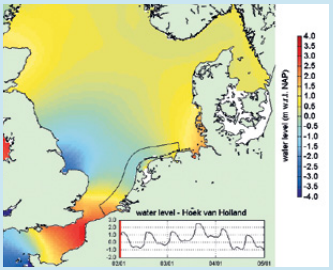
ap.vandongeren@deltares.nl
+31 (0)88 335 83 51

Delft Dashboard

a quick set-up tool for coastal models



Tsunami Japan 2011

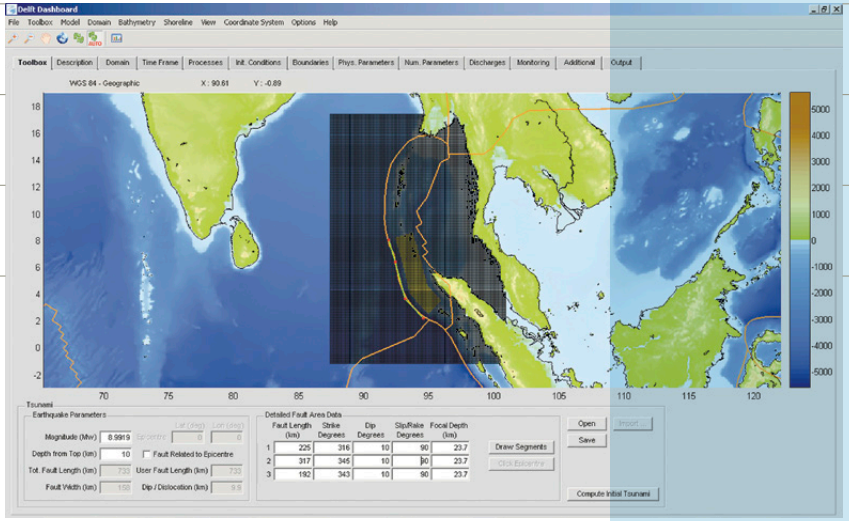


North Sea storm surge - January 1976

Coastal safety assessment studies, coastal management, coastal development and coastal operations now routinely incorporate results from numerical models. Much model development has focused on incorporating complex physical processes in order to improve the quality of the models in terms of predicting water levels, currents, waves and morphological change. As complexity increased, a need arose for increased availability, quality and detail of input fields into the model, such as initial topography and bathymetry, and tidal boundary conditions. Until recently, this information, if available, was either not in a digital form or not in a format that could be easily read by the model. In either case, setting up a model was cumbersome and it could take weeks before meaningful computer simulation became possible. Moreover, highly-trained engineers were needed to set up a model, adding to the cost of these studies.

With the advent of the Internet and the standardisation of formats for data, it has become much easier to draw data from various sources. Delft Dashboard has therefore been developed, making major reductions in the work needed to set up Delft3D models. The time spent on setting up models has been reduced from one week to a few hours, so more time can be spent on the real issues that coastal engineers are trained for: assessing the coastal impacts of various measures.

The Delft Dashboard tool uses an advanced graphical user interface which asks the user only to define a model area on a world map by clicking the corners of the domain. The tool then obtains the bathymetry, topography and boundary conditions from various internet databases. Within minutes, the user can start to run the model for historic or present cases, and compare them to online and archived datasets of, for example, tidal stations within the domain.



Detail view of a coastal model being set up for the Sumatran Boxing Day tsunami

At the moment, Delft Dashboard has dedicated tool boxes to generate severe storm and hurricane wind fields (by specifying the predicted track and intensity of the storm) in order to predict near-future inundation of low-lying coastal areas. Because the toolbox saves so much time, it was possible to produce numerous scenarios for hurricane landfalls in the US coast of the Gulf of Mexico.

The toolbox also has a tsunami generator which can generate devastating waves based on information about the strength, location and extent of an underwater earthquake. With this toolbox, Deltares was able to demonstrate the potential impact of the Chilean Tsunami of 2010 before the waves reached the opposite shores of the Pacific.

Recently, the US Navy acquired the Delft Dashboard toolbox for its coastal operations. Deltares will be developing the toolbox further to meet the Navy's requirements.

Further reading

http://public.deltares.nl/display/OET/DelftDashboard

Partners

- US Navy
- Ecoshape

Contact

jebbe.vanderwerf@deltares.nl
+31 (0)88 335 79 59

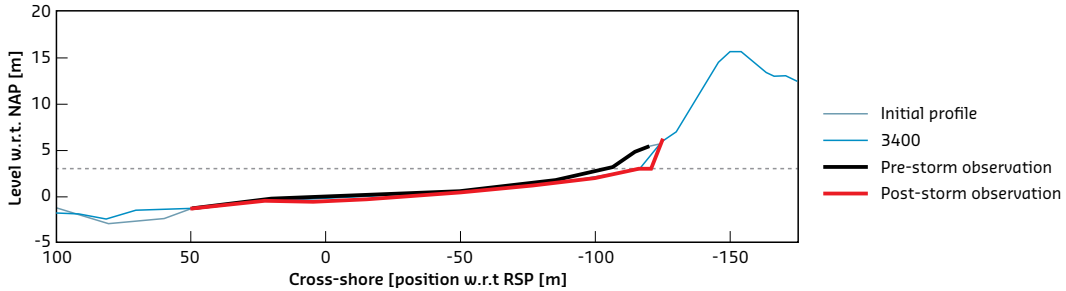
ap.vandongeren@deltares.nl
+31 (0)88 335 83 51

Real-Time Safety on Sandy Coasts

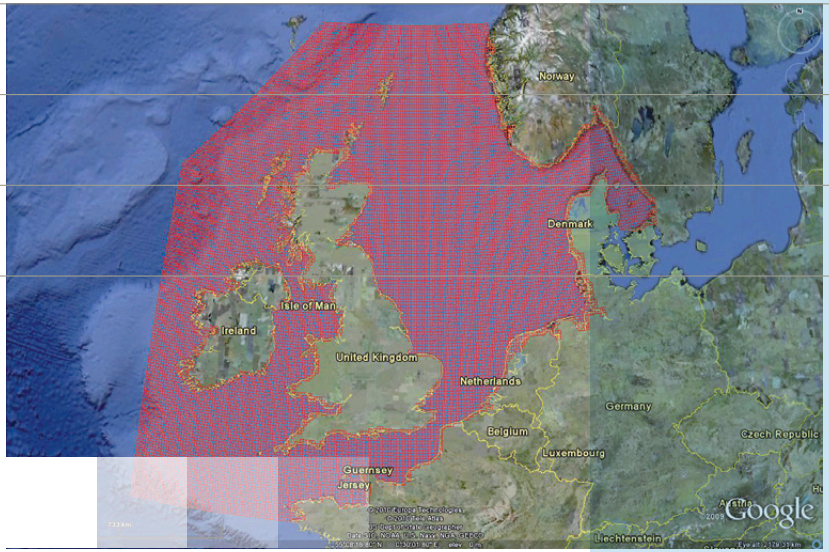
Being a good coastal manager is not easy. It requires fast and sound decisions about complex problems involving large margins of uncertainty with potentially major consequences. For example, coastal managers have to decide whether or not to evacuate coastal towns in the event of storms, or whether or not to close off part of a beach on a nice summer day when strong offshore rip currents are expected.

In the Flood Control 2015 project *Real-Time Safety on Sedimentary Coasts* Deltares, Arcadis (both NL) and Fugro GEOS (UK) joined forces to develop an operational modelling system (OMS) for the real-time monitoring and forecasting of water levels, current velocities, beach erosion and dune erosion. This accurate and up-to-date information supports coastal management decisions.

In 2010, we set up an operational model system to simulate storm impacts on the Dutch coast. It consists of four coupled numerical models – with a decreasing domain and an increasing resolution – to simulate flow, waves and nearshore morphodynamics with meteorological forcing from numerical weather models.



Initial profile, pre- and post-storm observations and final profile predicted by XBeach for transect 3400 (Bergen aan Zee)



A hindcast using data from a large number of stations in the Dutch part of the North Sea shows that the amplitudes and phases of the most important tidal constituents, as well as surge levels, are well predicted, during both a calm and a stormier month. Wave heights are predicted accurately for the stormy period, but overestimated for the calm period. This is due to errors in the wind forcing and swell boundary conditions, and possibly inadequate swell propagation modelling by SWAN.

The January 1976 storm event was used for the morphodynamic validation of the model system. When observed water levels are used as input instead of the underestimated levels, the XBeach models generally predict dune erosion well. As an example the figure shows the measured and predicted beach and dune erosion at Bergen aan Zee. In addition to hindcasts, the operational system can be used to make 3-day forecasts of water levels, wave heights, currents and dune erosion on this section of the Dutch coast.

In the near future the OMS application will be improved further. One of the key topics that will be addressed is the translation of the model output into coastal hazard maps that are useful for coastal management decisions. Furthermore, the OMS will be used to simulate wave and current patterns for Dutch beach sites in relation to safety for bathing.

Further reading

J. van der Werf et al.. *Operational model to simulate storm impact along the Holland coast*, Coastal Sediments Conference 2011, Miami, USA

Partners

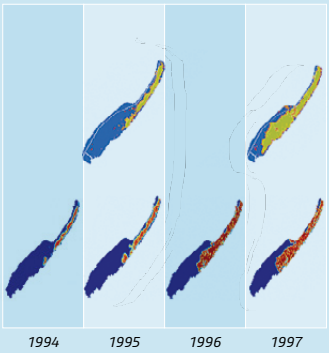
- Arcadis
- Fugro GEOS (UK)

Contact

arjen.luijendijk@deltares.nl
+31 (0)88 33581 09

Development of an eco-morphological model for designing mega-nourishment operations

The innovation programme 'Building with Nature' focuses on ecodynamic development and design, creating opportunities to build while drawing on the dynamics of the natural system. During that process, the forces of nature are used to produce hydraulic engineering infrastructure and to create new opportunities for nature at the same time. One of the aims of Building with Nature is the collection and development of ecosystem knowledge in order to make building with nature possible and to develop expertise relating to the application of the Building with Nature concept.
One of the packages has developed a biogeomorphological model for the ecodynamic design of mega-nourishment operations like the Sand Motor



Measured (above) and simulated (below) spatial pattern of Characeae spp. in Veluwe lake 1994-1997

Biogeomorphology studies the influence of plants, animals, and micro-organisms on the development of the earth's surface and land formations. In the past decade, it has been a focus of increasing interest from researchers, stakeholders and managers. Biogeomorphological modelling is regarded as a useful tool for studying the related effects. The essence of biogeomorphological modelling is to identify and present the links between the hydrodynamic, morphodynamic, water-quality and ecological processes involved on the appropriate spatial and temporal scales. However, biogeomorphological modelling is still a new field in both morphology and ecology due to the large discrepancies between field data and computer models.

Recently, an innovative biogeomorphological model was developed within the framework of the Delft3D software. The system consists of two main components: a hydrodynamic module FLOW and a process-based transport module WAQ. In addition to the huge number of processes affecting water quality, ecology and morphology that can be configured and extended

Nisqually estuary before dike removal (left) and 7 months after dike removal (right)
(from Google Earth)

individually in WAQ, a dynamic biological-population module has been developed. This module includes the interactions between vegetation and currents, wave dissipation, sediment transport, and bed forms in the coastal zone.

The dynamic vegetation-population processes were validated by reproducing the spatial pattern of two species in a semi-closed inland lake. The model can accurately reproduce the observed spatial pattern of the vegetation species in the Veluwe Lake (Netherlands). In addition, vegetation dynamics and morphological change in a wetland near Puget Sound (USA) was also studied using this model. There are plans to restore the area by removing the dike ring along the seaside. The ecological features reproduced with the model were first compared with the satellite images. The comparison shows that vegetation processes have a significant impact on morphological development.

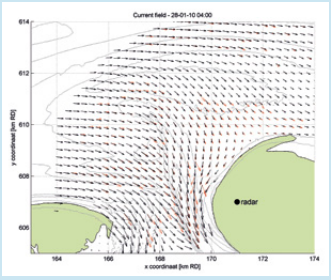
Partners
Ecoshape

Contact

cilia.swinkels@deltares.nl
+31 (0)88 335 83 64

Using navigation radar images to analyse spatial current fields in the Ameland tidal inlet

Ameland lighthouse
(Wikipedia Creative Commons 2007)



Computed currents (black) and radar data (red arrows) at maximum flood flow

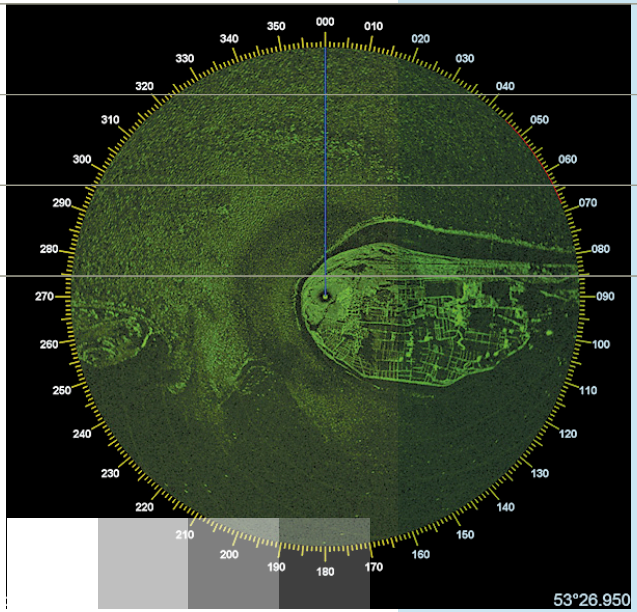
Our coastal flood defence system of dikes and dunes is expected to withstand extreme water levels and wave conditions. Safety assessments are carried out every six years to check whether these flood defence structures still meet statutory safety standards. The assessments are required to identify the structures that need improvements.

So far, the safety assessments have not been completely successful, as the prediction of extreme conditions still involves many uncertainties. The Strength and Loading of Flood Defences Programme (SBW) includes the research needed to fill in these knowledge gaps and to help improve the safety assessments.

One of the SBW research topics is the penetration of North Sea waves into the tidal inlet systems of the Wadden Sea. Their complex geometry makes the computation of wave propagation through tidal inlets difficult, and this leads to uncertainties in the prediction of extreme wave conditions in the Wadden Sea.

To model wave propagation through tidal inlets accurately, it is important to correctly include the water level and currents in the mouth of the inlet. A proper picture of these environmental conditions depends on extensive field campaigns. Even these campaigns generate only scarce data about current time and place, and do not greatly enhance our understanding about the complex current patterns in tidal inlets.

Since the beginning of 2010, however, analysis software has been linked to the navigation radar at the Ameland lighthouse. The software (SeaDarQ) processes the radar data and derives spatial information about waves, water depths and currents from the radar images. This novel remote-sensed data provides a unique opportunity to assess the temporal and spatial propagation pattern of waves and currents over the whole tidal



Raw radar image
(source Tech5)

inlet. The spatial coverage of the radar data contrasts sharply with the point information obtained from conventional in-situ measurements.

In this study, a comparison was made between the current fields derived from the radar images and numerical model results (Delft3D) for a storm event in January 2010. After the tuning of the model, the correlation between the model results and the radar data was found to be extraordinarily good. There was a strong match, even for complex flow phenomena such as eddies, tidal flow reversal and flow divergence over the ebb tidal delta. A crucial element in achieving this match was the incorporation in the model of roughness characteristics that varied in space. The match ultimately achieved between the data and the model has increased our confidence in the performance of both the SeaDarQ system and Delft3D.

The study showed that radar data is a very valuable data source that will certainly be explored further in future studies. The spatial detail of the radar data will allow us to calibrate our numerical model not only for water levels but, in the future, also for currents, which will improve the prediction of extreme current and wave conditions in the Wadden Sea area.

Further reading
Deltares (2011). Storm hindcast January 2010 – *Analysis of the application of radar current data for hindcast purposes.* (kennisonline.deltares.nl)

Partners
Tech5 B.V.

Contact

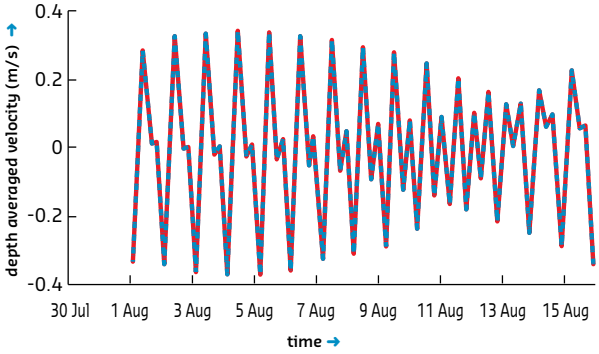
robin.morelissen@deltares.nl
+31 (0)88 335 83 14

qinghua.ye@deltares.nl
+31 (0)88 335 79 19

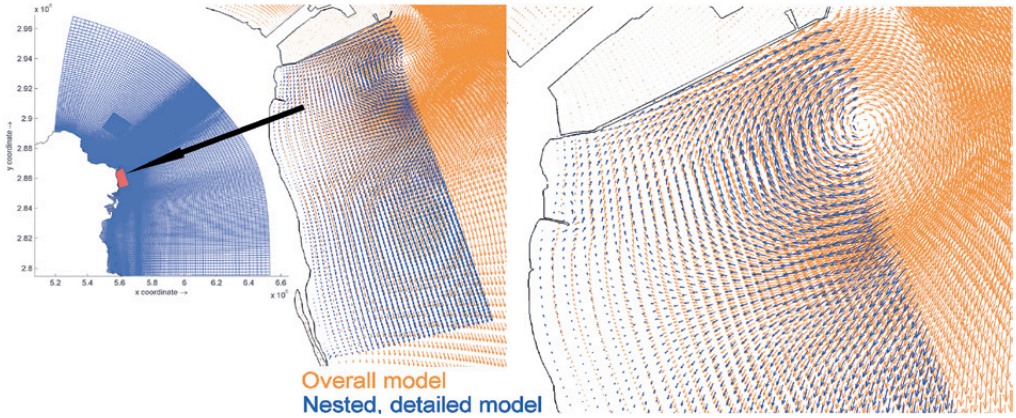
Flexible model nesting for efficient application of detailed flow models

All over the world the coastal infrastructure is expanding, with harbours, reclaimed land, channels and artificial islands being developed in the coastal zone. These developments interact with their environments and the other developments in their vicinity. Consequently, it is important to be able to assess the expected effects of these developments during construction and use. Water quality, ecology, morphology and navigation are some of the areas affected. The assessments often start with a study of changes in flow patterns caused by the proposed development.

The Deltares Delft3D-FLOW software is used for many hydrodynamic modelling studies. In many effect studies, detailed assessments require the modelling to include different spatial scales; starting with coastal zones around the development (kilometre scale) down to detailed effects close to the development (metre scale). This large range of spatial scales often makes hydrodynamic modelling time-consuming due to the size of the models. In complex flow environments, however, it is often necessary to include the overall models in order to correctly reproduce the large-scale flow patterns that drive the local flow in the area of interest.

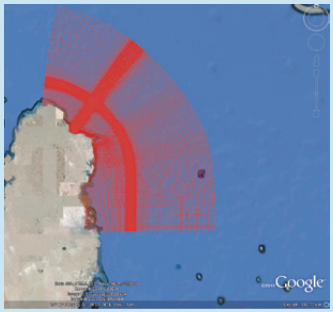


Comparison of the current in the overall model (red) and nested detailed model (blue).



There are different modelling techniques for dealing with this issue. A detailed modelling domain around the development can be constructed in an overall model using *domain decomposition*. In this way, the detailed model is dynamically coupled (in a two-way link) to the overall model and the large-scale flow patterns are reproduced well in the detailed model. This means, however, that the overall model domain also has to be included in the model run in each simulation, and so the operation remains time-consuming. The alternative is to *nest* a detailed model in an overall model. This technique involves coupling the overall model to the detailed model in a one-way arrangement. Once the boundary conditions of the detailed model have been derived from the overall model, the detailed model can run independently. Until now, however, this nesting technique could not be applied in complex flow environments due to limitations in the boundary conditions of the detailed model (flows could not enter the detailed domain at an angle, for example).

This project developed new boundary condition types for the hydrodynamic model so that a detailed model can now be reliably nested in a complex flow environment. In this way, simulations for different layouts can be completed much more efficiently and flexibly, enhancing the overall comprehensiveness and quality of the studies in question. The example in the figure shows a nested detailed model next to a harbour that can reproduce the complex flow conditions at the boundary (eddy).



Location of tested models (Ras Laffan, Qatar)

further reading

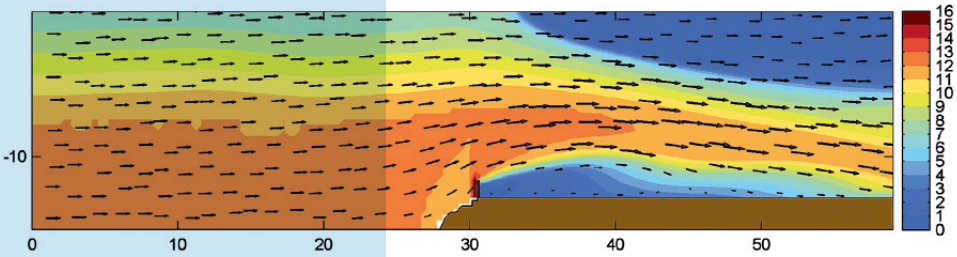
Ye, Q., Morelissen, R., 2010, *'Implementation and validation of tangential boundary conditions in Delft3D-FLOW'*, Deltares SO 2010 report (kennisonline.deltares.nl)

Contact

janjoost.schouten@deltares.nl
+31 (0)88 335 81 24

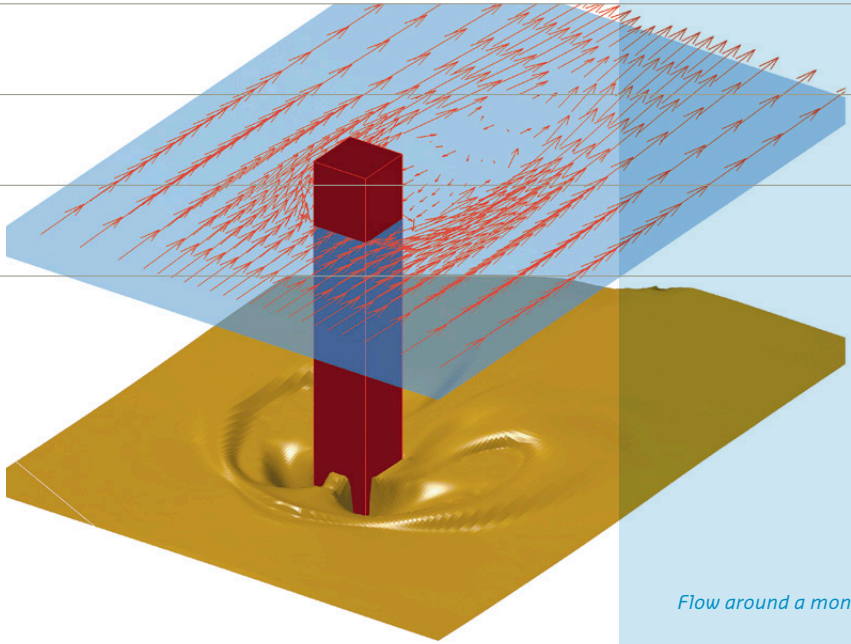
Non-hydrostatic modelling with Delft3D-FLOW

The application of three-dimensional hydrodynamic models for simulating free surface flows has become widespread in recent decades. In most of these applications the flows are of the boundary layer type, which means that the vertical acceleration component is relatively small. Under these circumstances, the vertical pressure distribution may be assumed to be hydrostatic. Delft3D-FLOW adopted this hydrostatic pressure assumption, which means that the numerical model is based on the "shallow water assumption".



Flow around obstacle

For some years now, there has been a tendency towards smaller scales. This means that more and more applications are becoming relevant in which vertical acceleration and, therefore, the non-hydrostatic pressure component can no longer be neglected. This is, for example, the case with flows over abruptly-changing bottom topography or for orbital movements in short wave motions. Delft3D-FLOW has a non-hydrostatic option as well. This option is linked to the "Z-model approach", in which strictly horizontal interfaces are used for the vertical layering. In 2010, the processes of sediment transport and morphology in combination with non-hydrostatic modelling with the Z-model were implemented successfully. As a result, the Delft3D-FLOW code has become more robust and, moreover, Delft3D-FLOW is now applicable to



Flow around a monopile

a much wider range of problem areas. These areas may include scour around offshore constructions, the development of a dredge plume and sedimentation in navigation channels.

The improvements have been tested in several projects. In the first project, measures were investigated to reduce saline intrusion from the North Sea into Dutch river estuaries. In that context, comparisons were made between the CFX package of ANSYS, one of the world´s leading software companies in computational fluid dynamics, and the non-hydrostatic option of Delft3D-FLOW. It emerged that, in a validation case with flow around an obstacle, similar results were obtained for the bed topography. The figure shows the velocities around the obstacle, with a clear vertical recirculation zone behind the obstacle. This scour pattern matches the measurements at monopiles with environmental conditions dominated by currents. However, the scour in front of the monopile (opposing the flow) should be more pronounced.

The second figure shows scour near a monopile. In this application, the Delft3D-FLOW non-hydrostatic model simulates the interaction between hydrodynamic, sediment-transport-related and morphological processes.

Further reading:
http://oss.deltares.nl

Contact

han.knoeff@deltares.nl
+31 (0)88 335 72 44

frans.hamer@deltares.nl
+31 (0)88 335 80 93

Exporting piping knowledge to Europe

The Mapping Netherlands Safety (2001 - 2015) project proved that the piping was an important failure mechanism. This confounded the expectations of dike managers. In projects conducted as part of the Strength & Load of Flood Defences (SBW) programme and the Flood Expertise Network (ENW), the accuracy of the prediction model and method for calculating probabilities of failure in relation to the length effect were investigated further.

Sand boils

The ENW piping committee looked at how piping can be taken into account in the development of the assessment and design tools to analyse the standards. The committee concluded that piping is an issue that can lead to dike failure and that the length effect is a factor that must be taken into account in design and assessment tools.

In order to approximate the uncertainties in the current piping models, the piping mechanism was examined in small- and large-scale tests. The experiments in the SBW project demonstrated that, when visible sand transport (substantial sand-boils) is observed, the dike will collapse due to piping given a constant water level. The critical head at which failure occurs depends on the geometry, the scale, and the strength of the subsoil. This investigation also concluded that the empirical rule of Bligh should not be used for testing and designing dikes and that the Sellmeijer assessment rule should be preferred in an amended form. The SBW project has developed a safety philosophy for applying the amended piping rule to assess and design dams and dikes. The state of the art security philosophy takes into account the model uncertainty, length effect and the safety standards.

SBW Full scale piping experiment

After the results of the SBW project investigation were approved by the ENW committee, the project made improvements to piping assessment. The amended Sellmeijer rule, which incorporates the safety philosophy, is central to the assessment. This assessment includes safe assumptions for the application of safety factors. If the dam or dike does not immediately comply with the safety requirements, an additional, and more detailed, analysis can be performed using more precise safety factors that may result in compliance with the safety standard.

The European FP 7 FloodProBE programme looks at whether the results are also applicable outside the Netherlands. It identifies the characteristics of European sands and compares them with the properties of sands in the Netherlands. Additional experiments will be carried out in 2011 to assess the validity of the amended piping rule in Europe. Furthermore, in 2011, different components of the assessment method will be studied in order to determine their applicability outside the Netherlands.

Further reading

- www.rijkswaterstaat.nl/sbw
- www.floodprobe.eu

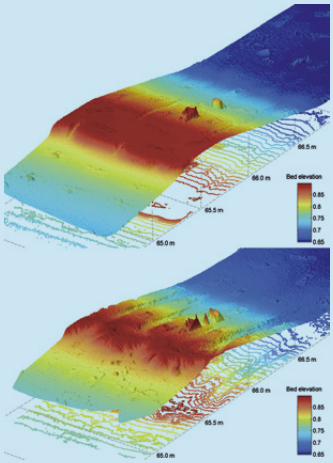
Contact

robert.mccall@deltares.nl
+31 (0)88 335 81 06

ap.vandongeren@deltares.nl
+31 (0)88 335 83 51

Numerical and physical modelling of barrier overwash during storms

Overwash simulation Santa Rosa Island. Waves come from below, yellow parts remain dry



Measured overwash-driven morphology of the scaled barrier island in the Scheldt flume

Approximately 10% of the world's coastline consists of barrier coasts, which are susceptible to dune erosion and coastal flooding. The need to predict the response of these coasts to storms is becoming steadily more pressing as the population in coastal areas is increasing worldwide and the loads on coastal systems are rising due to relative sea level rise and the possibility of more intense storms.

For most barrier coasts, overwash constitutes a natural response to increased hydraulic forcing by storm surge and waves. In order to manage overwash in areas where it is not desirable, or to reduce the consequences of overwash, a reliable predictive model is required to assess weak stretches of coast and coastal defence designs. Although it is obviously useful for coastal managers, our ability to quantitatively predict and simulate overwash and washover volumes is quite limited.

In the past year Deltares has been a leading partner, along with UNESCO-IHE, the United States Geological Survey and the University of Miami, in the development of an open-source numerical model called XBeach to predict barrier island erosion, overwash and inundation during storms. The model is unique in the way it integrates all aspects of storm-induced morphology in both the cross-shore and the longshore direction in a process-based way.

XBeach was validated by means of a hindcast of the morphological response of Santa Rosa Island, Florida, to Hurricane Ivan (2004). During the validation an XBeach model was set up of an eight-kilometre stretch of the barrier island, which was forced using surge and wave boundary conditions based on measurements and large-scale model simulations. The morphological response

Simulating overwash on a scale-model of a barrier island in the Scheldt flume

in the model was compared to measured pre- and post-storm LIDAR data. The model was able to reproduce morphological features common to overwash events and provided quite accurate quantitative hindcasts of the measured bed level change of the barrier island. During validation, it was found that the model response was sensitive to the sediment transport relations during overwash conditions.

In order to improve and validate the model formulations during overwash, a physical model experiment was carried out in the Scheldt Flume at Deltares, as part of the Strengths and Loads on Water Defences (SBW) program and the EU-MICORE program. In the physical model experiments, a scaled barrier island based on the Dutch Wadden Islands and Florida barrier islands was subjected to increasing hydraulic loads until overwash and inundation occurred. These experiments have generated a novel open-source dataset of the temporal three-dimensional morphology and hydrodynamics of a barrier island during overwash. These data are being used to investigate the validity of the hydrodynamic and sediment transport relations in the XBeach model as well as to improve insight into overwash and breaching processes.

Further reading

McCall, R.T. et al., 2010. *Two-dimensional time dependent hurricane overwash and erosion modeling at Santa Rosa Island.* Coastal Engineering, 57: 668-683. doi:10.1016/j.coastaleng.2010.02.006.

Partners

- UNESCO-IHE
- USGS
- University of Miami
- EU FP7 Micore

Contact

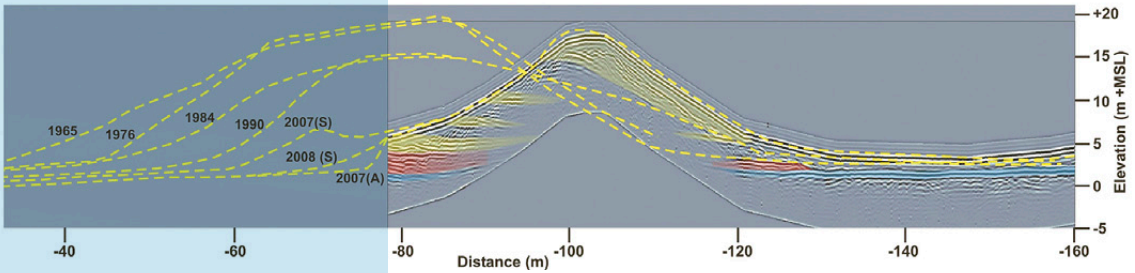
ad.vanderspek@deltares.nl
+31 (0)88 335 71 56

Unravelling Dutch Dune Dynamics

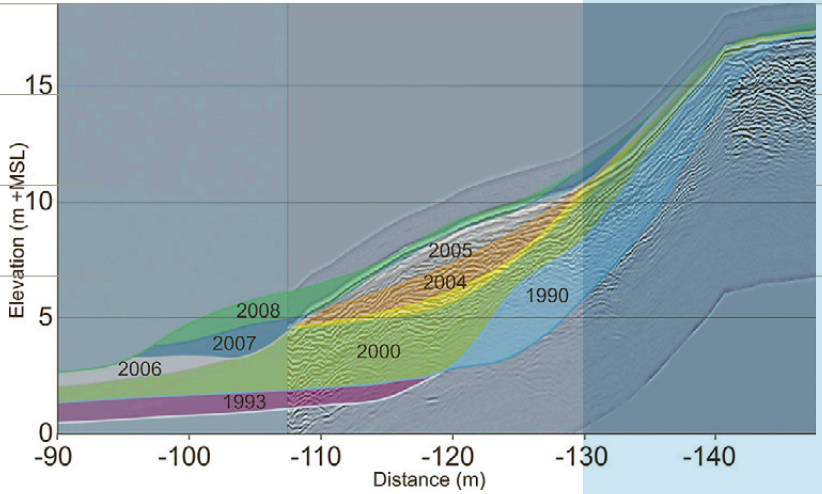

Photo: Marcel Bakker

Much of the Dutch coast is subject to structural erosion. A policy of dynamic preservation has been implemented since 1990, involving sand nourishment at selected locations along the coast. The development of the coast is monitored annually in coastal-profiling transects. Analyses of monitoring data, combined with visual inspection, have shown that structural erosion has decreased or even switched to coastal progradation since the implementation of the new policy. However, the monitoring data supply only limited information on the geological processes behind the observed changes, mostly because of the relatively low measurement frequency and lack of integration with other data types.

The aim of this study is to establish the internal architecture of the beach-foredune area and to determine the decadal-scale preservation potential of the deposits under the present nourishment policy. This goal is achieved by integrating ground-penetrating radar (GPR), hand auger boring and coastal-monitoring data from two sites on the coast of the western Netherlands, and combining these data with meteorological and other process information. This procedure can be applied at any desired location on the coast.



Migrating foredune, Heemskerk aan Zee



Seaward migration of the foredune, Bergen aan Zee

There have never been any sand nourishment operations at Heemskerk aan Zee. Here, the foredune foot was eroded by 1.0 m/yr in the period 1965-2008. GPR imaging reveals historical storm-surge deposits within the foredune, as well as sequences of aeolian sediment accretion to the landward side of the frontal dune.

At Bergen aan Zee, coastal erosion has been stopped by frequent sand nourishment. As a consequence, the dune foot migrated seaward by 30-50 m during the period 1990-2008. GPR shows a number of sediment bodies within the prograding foredune, including nourishment embankments, several wind-blown units derived from nourished sand, and prograding beach deposits. Integrating annual monitoring data and GPR shows that the accreted volume consists of water-lain embankments constructed in 1990/91, upper beach sands deposited in 1993, sand from nourishment operations in 2000 (partly water-lain, mostly wind-blown) and wind-blown nourishment sands from the period 2001-2008. The net volume of accumulation ranges from 180 to 233 m^3/m over a lateral distance of 530 m.

Almost all sand from nourishment prior to 2000 has been washed away. The analysis of meteorological data suggests that 1999 storm surges were responsible for this erosion. Since 2000, there has been structural accumulation along the dune foot in the form of nourishment sand redistributed by wind. This relative longevity can be attributed to a combination of successive shoreface nourishment operations and favourable meteorological conditions.

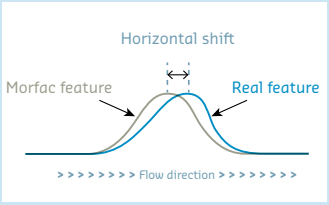
Further reading

M.A.J. Bakker et al., *GPR imaging of recent coastal-dune development: effects of sand nourishments* (kennisonline.deltares.nl).

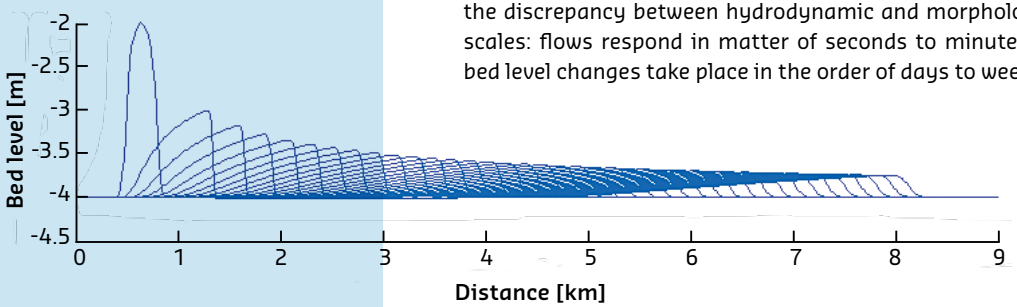
Contact

arjen.luijendijk@deltares.nl
+31 (0)88 335 81 09

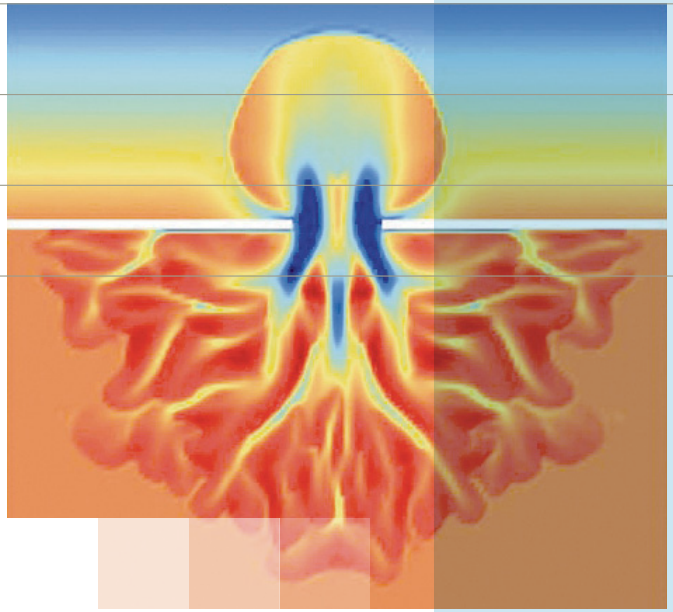
Reasons for Morphodynamic Upscaling



The long-term prediction of the morphological evolution of the coastal zone in response to climate change, human interference or a changing local environment has become increasingly important. Coastal engineers and managers worldwide have long felt it necessary to predict coastal morphological evolution using a numerical model covering time scales of decades. Until recently, it was only possible to simulate coastal evolution over periods of only a few years using traditional modelling approaches such as the 'continuity correction' method. However, this situation changed with the introduction of the concept of the morphological acceleration factor (MORFAC) to coastal morphodynamic modelling by Lesser and Roelvink. The MORFAC approach makes it possible to conduct efficient numerical simulations of coastal morphological evolution due to waves and currents over periods of decades. The approach is based on the principle of upscaling bed development during a simulation. This upscaling is justified by the discrepancy between hydrodynamic and morphological time scales: flows respond in matter of seconds to minutes, whereas bed level changes take place in the order of days to weeks.



However, the validity and limitations of the MORFAC approach have not yet been evaluated in coastal morphodynamic simulations at typical engineering time/length scales. In response to this shortcoming, a comprehensive, multi-year research initiative was recently initiated in a strategic alliance involving Deltares, UNESCO-IHE and Delft University of Technology.



Bed evolution in a tidal basin

The first step involved studying the effects and limitations of the MORFAC concept in coastal morphodynamic modelling for a 1D unidirectional flow case in an analytical model, a simplified numerical model and the Delft3D model. These models were used to analyse the sensitivity of the MORFAC in a parametric study of Froude numbers, sediment transport factors, friction parameters, Courant numbers and points per wavelength. A criterion for the maximum allowable MORFAC was then derived that satisfied the requirements of both stability and accuracy. It was found that the MORFAC approach performed better in the analytical and simplified numerical model than in the Delft3D model.

After an investigation of the sensitivity of both the accuracy and stability of the morphological model for all the relevant parameters, it was possible to deduce generic criteria for applying a MORFAC. Although it is still only applicable to some very specific cases, these criteria replace the time-consuming trial-and-error search for the optimal upscaling factor.

In conclusion, this study has provided valuable criteria for assessing the optimal upscaling factor for morphodynamic modelling, allowing for highly efficient simulations without affecting accuracy.

Partners

- UNESCO-IHE
- TU Delft

Contact

raymond.vandermeij@deltares.nl
+31 (0)88 335 7538

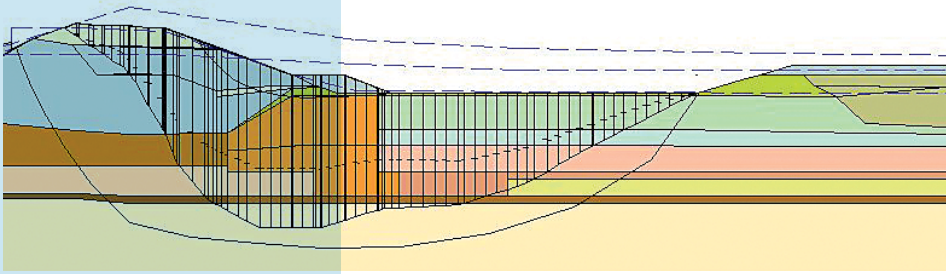
Artificial Intelligence for dike assessment

Bishop's method is often used to determine the stability of an embankment. This method assumes circular slip planes defined by a centre point and a radius. The weight of the soil mass at the top of the circle is the driving force behind the mechanism; shear resistance along the perimeter counters this driving moment. An engineer looks at different centre points and radii to find the representative slip plane for the embankment.

There are two fundamental shortcomings to this method. The first was encountered at Streefkerk in 1984. There were dangerously large deformations in the dike up to hundreds of metres behind it. These deformations could not be explained by Bishop's theory. Indeed, the embankment did not fail over a circular, but over a quite long horizontal, slip plane. The second shortcoming is that Bishop's theory does not satisfy horizontal equilibrium. This is why we did not predict the failure of the flood protection embankment at Wilnis in 2003. The long drought meant that the horizontal component generated by the force of the water became too significant to neglect.

Specific additional models can be used if Bishop's theory is expected to prove inadequate. Lift-Van describes the uplift phenomenon, and horizontal equilibrium must be checked

Slide at "Bergambacht" testing site using the free slip plane



"Bergambacht" testing site in practice

during drought. These additional models must be applied if it is expected that Bishop's will fall short but it is difficult to predict beforehand when this will be the case. This makes a safety assessment difficult and prone to subjectivity.

Spencer's model overcomes the shortcomings of Bishop's model. All equilibriums (horizontal, vertical and the driving moments) are satisfied, while the choice of the shape of the slip plane is entirely a decision for the engineer. The latter explains why the model is not used frequently. Finding the right centre point and radius in Bishop's model is already difficult, but finding the representative unconstrained slip plane is virtually impossible with conventional optimisation techniques.

In the world of Artificial Intelligence, such optimisation problems are more common practice and there are techniques for solving them. A genetic algorithm makes it possible to find the unconstrained slip plane with Spencer's method. The combination of Spencer's method with the genetic algorithm predicts the failures at Streefkerk and Wilnis properly, and it also gives the right solution where Bishop's method applies. The calculation time is similar to a conventional Bishop analysis while the need for other checks (Lift-Van, horizontal equilibrium) is eliminated. This unambiguous method is implemented in DGeoStability, allowing the engineer to make more precise safety regulations in a single analysis in the familiar interface.

Further reading

Van der Meij, R. and J.B. Sellmeijer. *A Genetic Algorithm for Solving Slope Stability Problems: from Bishop to a Free Slip Plane*, in 7th European Conference on Numerical Methods in Geotechnical Engineering (NUMGE). 2010, Trondheim.

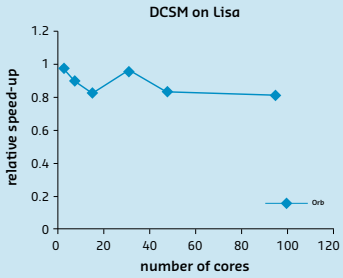
Partners

Flood Control 2015

Contact

edwin.spee@deltares.nl
+31 (0)88 335 82 29

High-Performance Computing with SIMONA

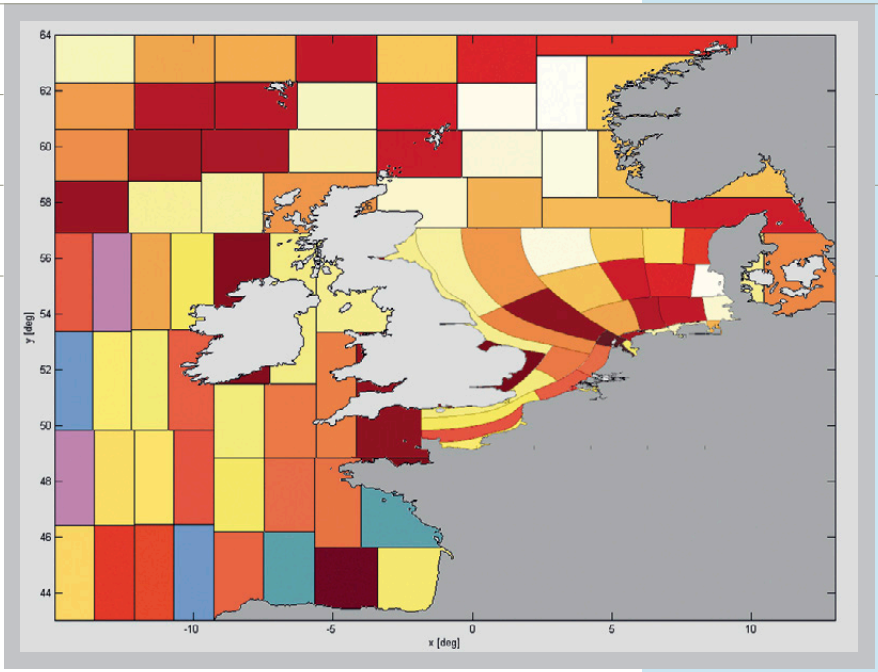


Scalability of performance up to 100 processors

Simulating water levels on the Dutch coast in an operational mode requires high-performance computing, which is more or less synonymous with "parallel computing". As far back as the late nineties, VORtech Computing developed a parallel implementation of WAQUA and TRIWAQ, which are hydrodynamic codes for 2D- (depth-averaged) and 3D-modelling respectively using the framework of SIMONA, the Rijkswaterstaat's hydraulic software suite. This parallel implementation works very well, with near-optimal speed-up on tens of processors. In the past, a maximum of sixty-four processors were applied in parallel for SIMONA simulations. This ran about 60 times faster than any single-processor simulation, resulting in a relative speed-up of 0.94.

Parallel implementation was further improved in SIMONA in 2010. After the 64-bit version of SIMONA became operational, it was installed in the Lisa supercomputer of SARA Amsterdam, which is the Dutch National High- Performance Computing Centre. The Lisa supercomputer uses Infiniband connection links between processors, and this results in considerable acceleration in parallel computing. In 2010, Deltares was invited to participate in the Wim Nieuwpoort Award, which is a high-performance computing challenge. As part of this venture, attempts were made to run the TRIWAQ code on more than 64 processors and observe the relative speed-up.

The parallel processing was tested on a model of the Dutch Continental Shelf: the North Sea and the adjacent region of the North Atlantic. The partitioning of the model into 96 subdomains, each with its "own" processor, takes place automatically, given a certain number of processors. The test was performed in a three-dimensional (ten-layer) mode. 3D-modelling is necessary



Partitioning of the parallel computing. Every "block" has its own processor

to simulate salinity and temperature stratification and this is essential to simulate, for example, the spread of the freshwater Rhine plume along our coast.

This 3D modelling requires a huge computational effort. With Lisa, up to about 100 processors, the speed-up scale follows the number of processors linearly. With more than 100 processors, we experienced software problems. In the end, we managed to run on 140 processors.

The North Sea model has an irregular geometry, because it is a real-life model. This is not ideal for scalability purposes. However, running a real-life model and showing scalability up to about 100 processors is much more convincing than running models that have been tuned for performance. It should be pointed out that these experiments were conducted without changing any code in TRIWAQ. It is expected that, with a relatively limited effort, it will be possible to apply a much higher number of processors in parallel mode.

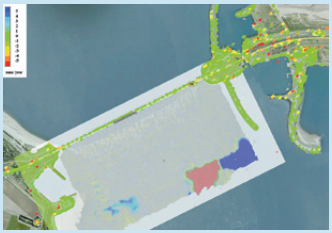
Acknowledgement
This work was sponsored by Stichting Nationale Computerfaciliteiten for the use of supercomputer facilities, with financial support from NWO.

Contact

bernadette.wichman@deltares.nl
+31 (0)88 335 72 04

mathijs.schouten@hansjebrinker.com
+31 (0)15 820 02 25

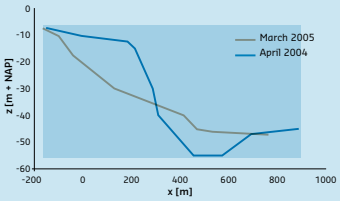
Dike deformation monitoring by satellite



Liquefaction at Noordland Binnenhaven dam, and PS-InSAR deformation speeds

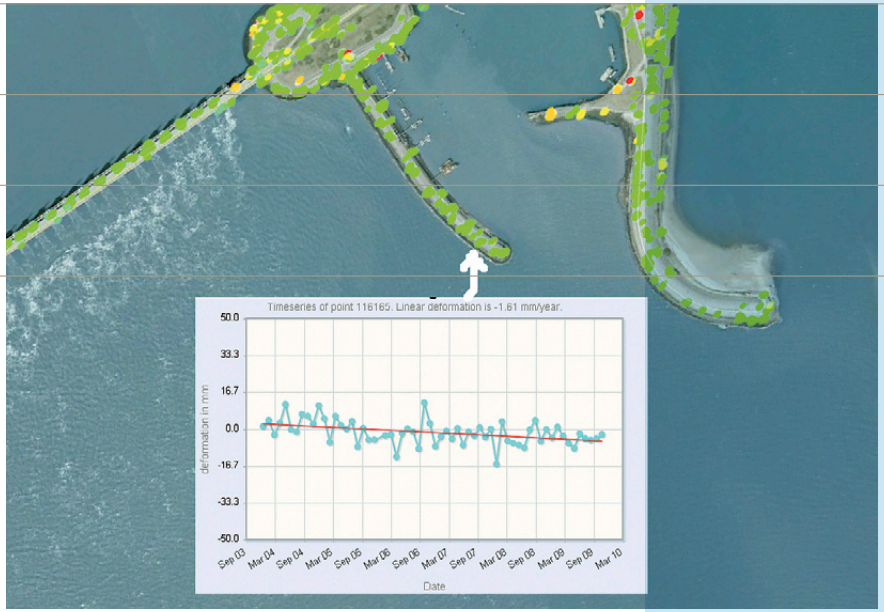
The stability of many Dutch dikes depends on adequate maintenance measures. Local water management authorities therefore depend on adequate monitoring of the deformation of dike bodies and the adjacent zones of influence. Particularly in the south-western delta (Zeeland) there are locations where deep gullies are very close to the dike bodies. Large tidal streams lead to erosion in these gullies. As a result, the depth of the gullies can extend to 50 metres and the slopes can be very steep. The slopes are covered with rip rap and accurate monitoring is required. The approach used for monitoring is multi-beam echo loading.

Nothing is known about the effects of the deep gullies on the deformation of the foreland and the dike, particularly in areas close to the gullies. As a part of the Flood Control 2015 project "Monstercase", a study took place to determine whether it was possible to monitor deformations of the dike body using Persistent Scatterers satellite radar interferometric monitoring (PS-InSAR). When the rate of deformations suddenly changes or when there is a local aberration, the water management authority may decide to investigate the cause. There may, for example, be liquefaction nearby. The condition of the subsoil also has an effect on these deformations.



Liquefaction effect as measured by echo sounding

One location where there was substantial liquefaction in the past can be found close to the Noordland Binnenhaven at the eastern side of the Eastern Scheldt storm surge barrier. Profiling with the multi-beam echo sounding indicates erosion with depth increasing up to 20 m in an area approximately 300 m wide (blue spot) and depth decreasing up to 10 m (red spot). Calculations showed that this liquefaction had occurred gradually over a period of 30 hours, indicating breaching. The breaching slope edge has progressed up to 100 m from the Binnenhaven dam, which is potentially dangerous.



Noordland Binnenhaven dam in more detail with example of deformation trend

The coloured spots in the figure indicate the average deformation speed of available persistent scatterers as identified with the PS-InSAR during the period between 2003 and October 2009. A persistent scatterer is a small part of the dam, for example a single stone, that settles or rotates in a gradual manner within a bandwidth of ± 3 cm. In this figure the dam is covered with green spots, indicating that the deformation speed of the persistent scatterers was between -2 and 2 mm/year in the period between 2003 and October 2009. The distribution of the scatterers is dense enough to determine the overall deformation of the dam close to the breaching location. As the deformation speeds are small over the entire period, it was concluded that this type of breaching, albeit potentially dangerous, had no effect on the stability of the dam.

Further reading

B.Wichman et al *Verkenning toepassingsmogelijkheden bij waterkeringen* (2010, in Dutch), at kennisonline.deltares.nl

Partner

Hansje Brinker

Healthy water and soil systems

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. Water and soil quality issues in relation to strategic and operational management (dealing with agriculture, cultivation, drinking water supplies) are also taken into account. Of course, water quality cannot be viewed independently from the water quantity issues in the next section.

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. As well as ecosystem services, the soil supplies groundwater (protection of strategic drinking water resources), 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.

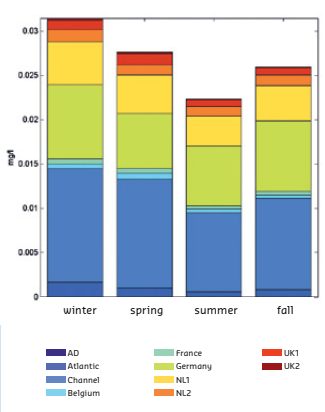
These issues result in five road maps: *Eutrophication and nutrients, Micro-pollution, Innovative design of ecosystems, Water quality monitoring and prediction* and *Ecosystem health and ecosystem services*.

Contact

hans.los@deltares.nl
+31 (0)88 335 85 49

tineke.troost@deltares.nl
+31 (0)88 335 82 81

KNOWSEAS

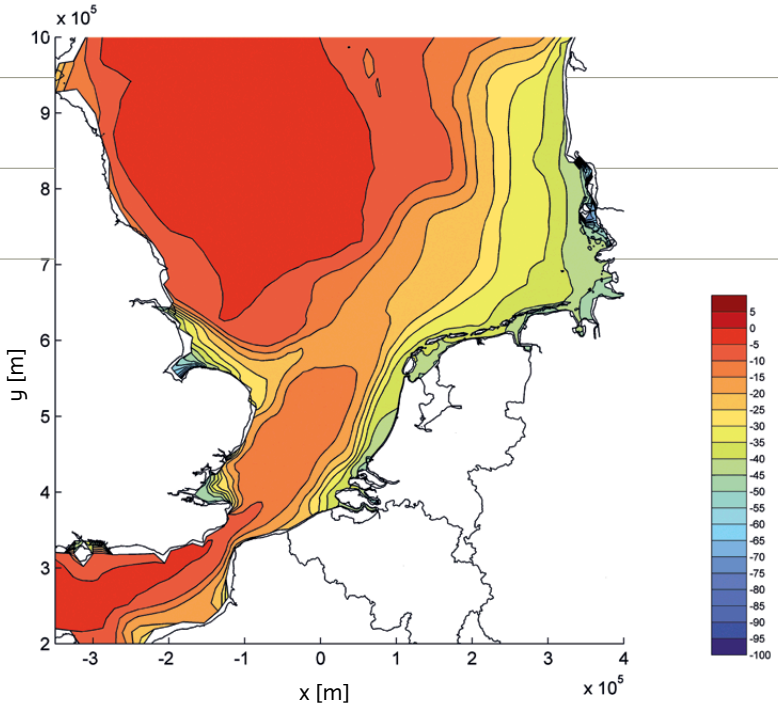


Phosphorus sources in the German Bight

Since the mid-20th century, there has been a growing awareness that, although Europe's seas have a relatively large volume, they are neither an infinite source for food (i.e. from fishing), nor a bottomless sink for substances such as nutrients, pesticides, heavy metals and other pollutants. Early international initiatives for managing regional seas, such as OSPAR, were later followed by the European Maritime Policy and the European Marine Strategy Framework Directive (MSFD).

The emphasis is increasingly on an ecosystem approach, taking into account the relationship between human society and the ecosystems that support it. Knowseas: *Knowledge-based Sustainable Management for Europe's Seas* is an important EU-funded project supporting these new management concepts. With approximately thirty other partners, Deltares has a leading role with respect to modelling, with a special emphasis on nutrients and primary production in the North Sea.

Traditional methods for assessing the impacts of management measures often show that a change in a pressure does not result in an equally large change in the ecosystem effect variables. For example, a 50 percent reduction of dissolved nitrogen in 76 rivers in our BLOOM/GEM model results in a change of less than 20 percent in chlorophyll. Moreover, spatial distribution is quite different due to non-linear ecosystem behaviour. Although models receive information about individual sources, their relative importance is not immediately obvious. To obtain this information, we have implemented a new, innovative labelling technique in the model to trace N and P sources individually. At each moment and location, we know the proportion of the tagged nutrient relative to the total amount of nutrient. When the nutrient is digested by organisms, the uptake ratio remains constant and so the contribution of each individual source remains known. Labels are assigned to ten sources (six



Impact of 50 percent reduction of N river discharges on winter level of N

combinations of regional rivers, the atmosphere, the Channel and the North Atlantic boundary) and maintained throughout all physical, chemical and biological processes. The label attached to a river is named after the country where it enters the sea even though other countries may contribute to its load. Further upstream discrimination of river sources with a similar labelling technique is feasible, but it is outside the scope of Knowseas. The bar chart shows a typical result for total phosphorus in the German Bight. In this area, several sources are important, in particular the German and Dutch rivers, but the Channel also makes a substantial contribution.

In the next few years, this new labelling technique will be applied to address issues such as: 'What will happen if a certain national or international policy is implemented?' as well as 'What is the most effective measure to achieve a specific target i.e. advance treatment in the UK or reduction of agricultural sources in the Netherlands'?

Further reading

Los, F.J et al., *A 3-dimensional primary production model (BLOOM/GEM)*, North Sea Journal of Marine Systems, 74 (2008) 259-294.

Contact

joachim.rozemeijer@deltares.nl
+31 (0)88 335 71 83

Dynamics in groundwater and surface water quality

Tile drains

Overland flow

Why is it so difficult to quantify and predict the effects of new agricultural practices introduced to improve water quality? Would the measuring of water quality parameters not be much more effective if we were to introduce more process-based knowledge into data interpretation and upscaling? These questions led Joachim Rozemeijer and Ype van der Velde to initiate a joint PhD project: DYNAQUAL.

DYNAQUAL stands for Dynamics in groundwater and surface water quality. The project started in 2006 and ended in 2011with two theses presented at Utrecht and Wageningen Universities. The main goal of DYNAQUAL was to understand the dynamics in groundwater and surface water quality at different temporal and spatial scale levels. We studied the dynamic behaviour of water and solute transport through an innovative multi-scale experimental setup in a lowland agricultural catchment.

Taking into account and understanding dynamics in water quality is essential for adequate water quality policy and management. In conventional regional surface water and upper groundwater quality monitoring, measurement frequencies are too low to capture the short-term dynamic behaviour of solute concentrations. We demonstrated that neglecting dynamics in water quality leads to misjudgement of the effectiveness of measures for improving water quality and to inefficient water quality monitoring. Furthermore, water quality management can benefit from a number of new methods for gathering and interpreting water quality information that were developed and evaluated in the DYNAQUAL project. For example, we demonstrated the value of a new passive sampling technique for measuring average concentrations and of in-situ analysers for continuous concentration measurements. Moreover, we presented different options for exploiting the explanatory strength of commonly

Experimental field setup for measuring all water and solute fluxes

available continuous measurements of quantitative hydrological parameters like precipitation, discharge, and groundwater levels. Through this approach, we improved the total yearly load estimate from low-frequency measurements for phosphorus from a 65% bias to a 5% bias and for nitrate from a 20% bias to a 1% bias.

The variability in solute concentrations at the catchment outlet is the result of field-scale water and solute transport processes. At an experimental field site, we captured all the water and solute fluxes from the field surface, directing them into a 45-metre-long ditch transect. We found that overland flow and tile drain effluent were dominant transport routes towards the surface water for many agrichemicals. For example, the tile drains contributed 90% of the yearly nitrate and heavy metal loads. The relevance of these small-scale and highly variable processes complicates catchment-scale water and solute transport modelling. We developed new modelling concepts based on groundwater level distributions and dynamic travel times to deal with short flow routes in regional water and solute transport modelling. After this extensive project, we conclude that sensible regional water quality modelling and monitoring should focus more on the dynamic behaviour of short flow routes like tile drain flow and overland flow.

Further reading

- PhD thesis Ype van der Velde *Dynamics of groundwater and surface water quality. From field-scale processes to catchment-scale models* (WUR 2011)
- PhD thesis Joachim Rozemeijer *Dynamics in groundwater and surface water quality* (UU 2010)

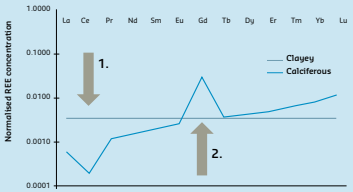
Partners

- Utrecht University
- Wageningen University and Research Center

Contact

marc.verheul@deltares.nl
+31 (0)6 57 56 50 66

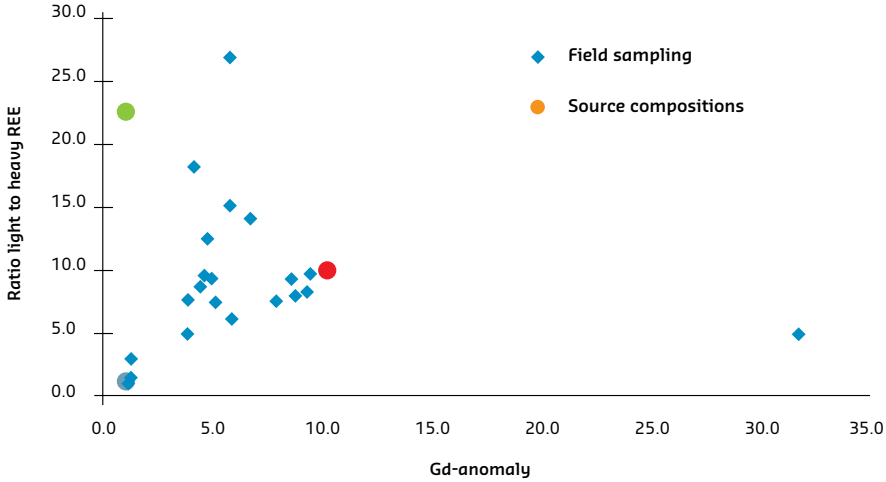
Rare earth elements as tracers



cerium (1) and gadolinium (2) anomaly

The concentrations of rare earth elements in Dutch ground and surface water are low at sub ppb (µg/kg) levels, but they can be measured using an optimised plasma mass spectroscopy method. The lanthanides behave almost identically in chemical terms and this results in concentrations in groundwater at a constant ratio between the different elements, although the absolute concentrations can vary by more than two orders of magnitude. The measured concentrations are divided by the levels in a reference clay mineral, yielding a flat line for samples with a clayey signature and a limited number of deviations. Water with a calciferous influence is enriched with the heavier REE rather than the lighter REE. The slope can be expressed by the quotient of the sum of the normalised ytterbium and lutetium values and the sum of the normalised lanthanum and praseodymium values. Specific anomalies can be attributed to specific causes. The cerium anomaly (a depletion) is a result of the preferential co-precipitation of cerium with iron(hydr)oxides during changing redox conditions. The gadolinium anomaly (an enrichment) is caused by the application of gadolinium as a contrast agent during medical MRI scans. This last anomaly is a clear indication of anthropogenic impact on the water/groundwater.

In a polder area in the Netherlands, between the cities of Tiel, Oss and Nijmegen, the influence of the inlet of Meuse water during the summer months on the nutrient concentrations in the surface water was unknown. In order to establish a picture of the water balance in the area, 22 locations were sampled during a period of active inlet of Meuse water. Based on the gadolinium anomaly, the signature of each of the locations is marked in a map. The size of the dots represents the size of the gadolinium anomaly.



The red dots indicate the locations where mainly Meuse water is present, the white dots are located in the capillaries of the water system and contain mainly ground- or rainwater, and the yellow dots represent the larger waterways that contain a mixture of Meuse and local water.

The slope was plotted against the size of the gadolinium anomaly for the samples and for the sources Meuse water (red dot), rainwater (blue dot), and the groundwater in the polder area (green dot). All but two samples in the area are clearly mixtures of these three water sources, and their location in the diagram enables us to calculate the contribution of each source. One of the "mismatching" water samples is right next to a wastewater treatment plant, with a strong increase in the gadolinium anomaly. With this innovative technique it is possible to make a detailed water balance for complex hydrological systems.

Further reading

Klaver et al, 2009, *Natural versus anthropogenic sources in the surface- and groundwater dissolved load of the Dommel river*, Journal of hydrology, vol 369, issues 3-4, pp 336-349.

Contact

foppe.smedes@deltares.nl
+31 (0)88 3357 77 90

jasperien.deweert@deltares.nl
+31 (0)88 335 71 72

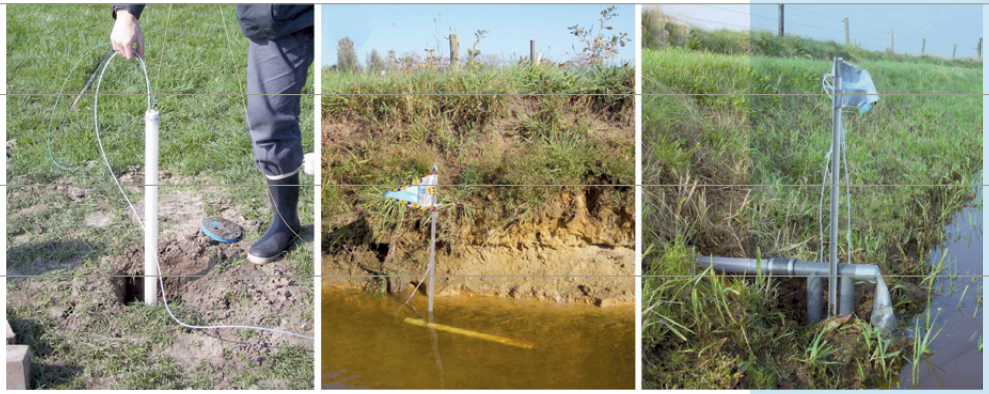
Passive sampling measuring concentrations of hydrophobic pollutants

Passive sampling is a powerful tool that establishes a picture of the chemical quality of water bodies by measuring the freely dissolved concentrations of various pollutants in water, even at extremely low levels. Freely dissolved concentrations represent a key measure of the bioavailable concentrations of pollutants.

A passive sampler consists of absorption material with a high affinity for the compounds of interest, in this case hydrophobic pollutants. Through a diffusion-driven process a passive sampler will absorb freely dissolved compounds from a large amount of water during its deployment (weeks to months) in surface water. The uptake rate depends on the dissolved concentration in the water and on the hydrodynamic conditions. Uptake is faster when turbulence is high.

Recently, a passive sampler made from silicone rubber was developed and applied. This silicone rubber sampler is easy to handle and extremely robust so that it can be used in the field for several weeks to months or, if necessary, a year. In situ calibration is used for calculating the freely dissolved time-averaged concentrations from the uptake of compounds by the silicone rubber sampler. Deltares also played an important role in the development of the water-sampler exchange model, which is needed to correct for the hydrodynamic conditions with in situ calibration. The model requires several physical properties of compounds, such as sampler-water partition coefficients and diffusion coefficients in sampler material.

Sampling device with silicone rubber passive samplers



The silicone rubber passive sampler has sorption properties closely resembling those of body lipids and therefore measure the relevant concentrations of pollutants. Concentrations in mussel tissue correlate very well with freely dissolved concentrations in water derived from passive sampling. There are similar correlations with concentrations of lipophilic compounds in body lipids of other organisms such as eels and cockroaches. It was therefore concluded that passive sampling with silicone rubber is a good alternative for environmental biomonitoring.

Passive sampling might also be an alternative for periodical classic grab samples collected over time. A short peak concentration is automatically included in the time-averaged concentration derived from passive sampling, whereas this peak can easily be missed by the periodical grab samples. Furthermore, the detection limits for compounds measured with passive sampling are much lower than for those measured in grab samples and also lower than required by the present quality standards. In the Waterharmonica Improving Purification Effectiveness project, silicone rubber samplers were used to investigate the efficiency of marsh areas in the further degradation of compounds present in outlet water from wastewater treatment plants. The measurements revealed that certain pesticides could be detected below the Water Framework Directive standard, which was not possible in classic grab samples.

Further reading

Smedes F. et al. (2010)
Het gebruik van passive sampling in KRW-monitoring (in Dutch), at kennisonline.deltares.nl

Contact

hans.vanduijne@deltares.nl
+31 (0)88 335 77 76

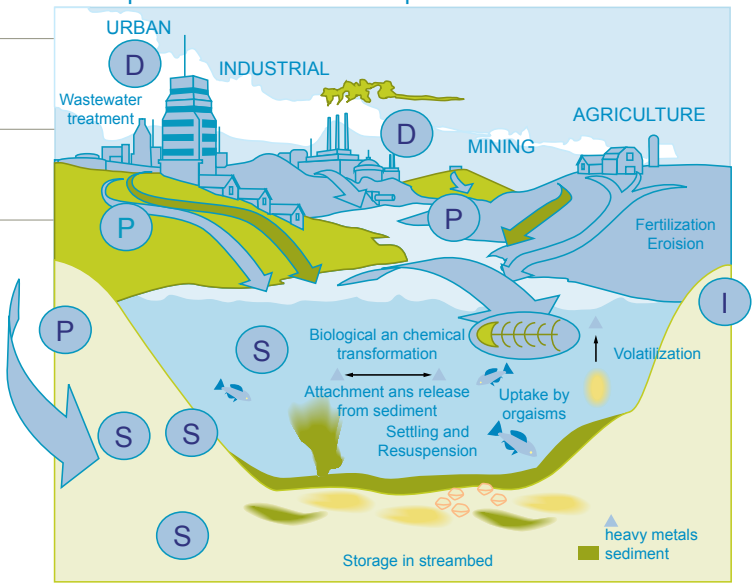
The AquaTerra project

The AquaTerra EU FP6 research project has developed knowledge for the integrated management of four European river basins. The project focused on issues integrating the modelling of river systems (water-sediment-soil-groundwater) and developing advanced instrumentation for land use and climate change at different scales and over different periods of time.
It appears that the large-scale input of anthropogenic compounds with uncertain long-term effects is still putting pressure on environmental systems. Increasing concentrations have to be expected in the environment at large temporal and spatial scales because of historical burdens built up in soil, sediment and groundwater during recent decades.

The European Water Framework Directive (WFD) requires the reversal of upward trends of pollutants in groundwater. It is, however, difficult to provide sound proof for a declining trend because of uncertainties about the travelling time of groundwater being sampled in monitoring wells. The age of the groundwater in monitoring wells could be determined by the tritium/helium isotopic dating technique. The technique is based on the decay of tritium (^3H) and the abundance of its product helium (^3He). This technique provides information about the travelling time of the water and, in combination with concentrations of contaminants like nitrate, a trend can be determined. Nitrate concentrations were found to decline after 1985, the year in which regulations for the use of fertilisers came into force. Groundwater dating made it possible to prove the effectiveness of these measures.

A groundwater model developed in AquaTerra was used to estimate the contribution of the groundwater contamination to surface water pollution. Contamination sources have been incorporated in the model and water managers can use scenarios to investigate whether processes can be influenced and to

Conceptual Basin Model and AquaTerra



examine the effectiveness of measures. The model was used for the design of a monitoring network and the monitoring results are used as input for the model. The results of the project in the province of North Brabant show that input from groundwater is the most important source of surface water pollution. Especially in wet conditions, when the upper groundwater reaches surface water through short flow paths in canals and by surface runoff, significant amounts of agricultural pollutants like copper, zinc and nitrate are transported to the surface water.

The soils, the river beds and the water in the Dommel river in North Brabant are heavily contaminated with zinc and cadmium from industrial activity in the past. An extensive inventory was carried out as part of the AquaTerra project. During this inventory, some elements that were not incorporated in regular monitoring programmes (Th, Ru, Co and Mo) were found in high concentrations. With an extended assessment and based on the results of this analysis, the water authority verified that the current approach to contaminated surface water is still appropriate.

Further reading

Trends in groundwater quality in relation to groundwater age,
Ate Visser, ISBN 978-90-6809-427-5
www.eu-aquaterra.de

Partners

EU FP6 Aquaterra with a.o

- Universität von Tübingen
- BRGM
- WUR-Alterra
- Utrecht University
- VU Amsterdam

Contact

jasper.griffioen@deltares.nl
+31 (0)88 335 79 29

stefan.jansen@deltares.nl
+31 (0)88 335 78 49

Innovative approaches to diffusive contamination

Field reactor for the removal of nitrate with ethanol injection in a ditch

Historical pumping station

The European Water Framework Directive (WFD) requires good ecological and chemical water quality. Several measures have already been taken to improve water quality, both within the framework of river basin management plans and in accordance with national legal or regulatory requirements. However, in spite of the measures taken, further water quality improvement is required in years to come. Pollution with nutrients from agricultural practice in the past and present is a particular problem. Both farmers and water authorities need complementary measures that will contribute to improvements in water quality.

Tile drainage below agricultural fields is an important pathway through which phosphorus and nitrogen enter surface water: it is estimated that half of the total Dutch agricultural area is drained. Tile drainage is also a physical entity that should be targeted by water treatment. In collaboration with the research institutes TNO and PPO (Wageningen University Applied Plant Research), as well as with a large number of governmental and agricultural organisations, potential treatment options are currently being tested.

The research identified two possible avenues for innovation. The first is the application of low-cost, slow-reaction, materials like wood chips for the removal of nitrate, or iron-coated sand for the removal of phosphate. The advantages are low costs and longevity, but the disadvantages are the large volumes of material needed. Because of these large volumes, these materials can best be applied in the tile drains. The second avenue is the use of more intensive methods, such as the removal of nitrate using ethanol or the removal of phosphate using electro-coagulation. The advantage is the small treatment unit needed, but high costs and technical complexity represent drawbacks.

Installation of tile drainage with wood cuttings

When water is pumped from polders, the receiving water is often loaded with phosphate and nitrate at undesirably high levels. A pumping station is a natural collection point and it can therefore be a convenient location for water treatment. In collaboration with two water authorities and Waternet, the technical and financial feasibilities have been assessed, with a focus on phosphate removal.

Both technically intensive installations and extensive technologies appear to be suitable for the removal of phosphate from polder water. The choice depends in part upon whether the phosphate is organically bound or free. Treatment can take place at the pumping station or in a recirculation system within the polder. The costs are comparable to those of other water quality measures such as helophyte filters. Further implementation is tailor-made, with space requirements and embedment in the regional water system being important factors requiring attention.

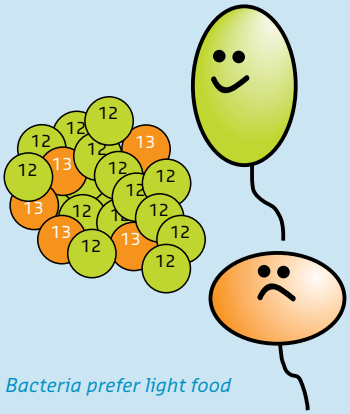
Partners

- TNO
- WUR-PPO

Contact

alette.langenhoff@deltares.nl
+31 (0)88 335 78 66

Innovative monitoring of MtBE



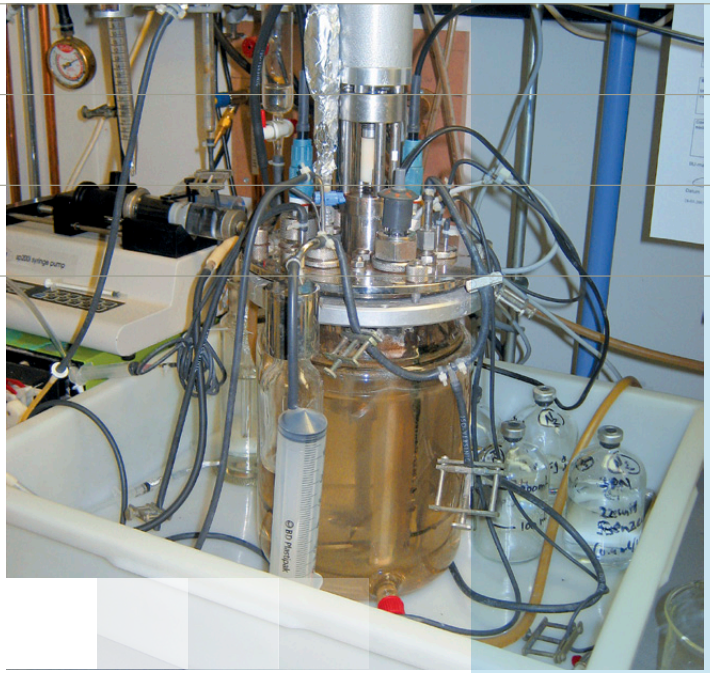
Bacteria prefer light food

Methyl tertiary-butyl ether (MtBE) is a fuel oxygenate added to petrol to improve fuel combustion and reduce the exhaust of carbon monoxide. It replaces lead and is widely used in Europe since the 1980's. MtBE is relatively inexpensive, easy to produce and blends well with petrol.

However, due to the abundant use of MtBE in combination with its high mobility and low degradation rate, MtBE became an important groundwater pollutant. MtBE negatively affects the taste and odour of water, and its intermediate degradation product tertiary butyl alcohol (TBA) is potentially affecting genetic material. Compared to BTEX-components, MtBE is more soluble and sorbs less to soil organic matter. As a result, MtBE often forms the leading edge of petroleum related contaminant plumes in groundwater.

An attractive option for cleaning up contaminated sites is monitored natural attenuation (MNA). Natural attenuation is defined as a reduction in mass or concentration of a compound in groundwater due to naturally occurring processes such as biodegradation. MNA is an acknowledged remedial approach under European directives, which means that it could also be used in, for example, duty of care situations and that it is in line with "sustainable" approaches. This makes MNA an attractive option for the cost-effective treatment of low-risk sites, or as a secondary remediation procedure in combination with active source removal techniques for high-risk sites.

In order to provide quick and direct tools to monitor the natural attenuation of MtBE at contaminated sites, a number of detection methods have been developed: real-time quantitative PCR (polymerase chain reaction – to multiply DNA material) and compound-specific stable isotope analyses.



Bioreactor with bacteria that degrade MtBE

The first monitoring tool to be developed is based on DNA analyses: real-time q-PCR analyses. Assays were developed that identify the presence of the genes of specific enzymes involved in the degradation of MtBE. The presence of these enzymes at a contaminated site indicates that MtBE degrading bacteria are present.

The second tool uses compound-specific stable isotope analyses. These analyses identify biodegradation by a shift in the stable isotope ratio of elements such as carbon ($^{13}C/^{12}C$) or hydrogen (D/H) in MtBE or its degradation products. Bacteria prefer to degrade the bonds in which the lighter stable isotopes are involved, and this results in the enrichment of the heavier isotopes in the residual contaminant. An increase in the isotope ratio in the remaining contaminant can therefore be used to demonstrate its degradation. The monitoring tools developed have been applied at several contaminated sites to demonstrate their added value in predicting the natural attenuation of MtBE. These tools make it possible to conduct an efficient site characterisation of degradation potential and rates. This can result in a Monitored Natural Attenuation (MNA) approach, which is an attractive, cost-effective strategy for contaminated sites.

partners

- BP
- Shell
- Vopak
- A&G

Contact

gualbert.oudeessink@deltares.nl
+31 (0)88 335 71 39

perry.delouw@deltares.nl
+31 (0)88 335 71 26

Flying high to map salinity

Fresh groundwater is a popular water resource for domestic, agricultural and industrial activities in coastal areas throughout the world due to the availability of huge quantities and the high quality relative to surface water. In the future, the use of fresh groundwater resources is likely to increase due to population rise (especially in megacities), economic growth, intensified agricultural development, and the loss of usable surface water due to contamination. Using more groundwater exacerbates salinisation, negatively impacting the exploitation of the groundwater resource for drinking water, and groundwater for agriculture and nature conservation. Sea-level rise and the associated changes in recharge and evapotranspiration patterns will intensify the pressure on this coastal groundwater.

The sustainable management of these groundwater resources worldwide often suffers from a lack of data. Mapping and monitoring the current spatial extent of fresh groundwater normally requires detailed in situ information about large areas, and this is seldom available. As an alternative, remotely sensed data are a cheap alternative for the quick acquisition of data covering large areas. This research looked at Airborne Electromagnetic (AEM) geophysical methods. These AEM methods are particularly suitable for detecting the salinity of groundwater due to the impact of salinity on electrical conductivity. Complicating factors include the effect of man-made infrastructure transporting electrical currents (power lines, railways) and the effects of the underlying geological structure. Both salinity and lithology affect the response of the EM system and it is therefore important to be able to unravel the combined effect of these factors.

The HEM bird of BGR

Deltares works together with institutes such as TNO, BGR, Aarhus Geophysics and Fugro to make these AEM methods suitable and accessible for stakeholders mapping fresh groundwater resources over large areas. Pilot studies in the Netherlands, Denmark and Germany conducted as part of the Interreg IV-B project CliWat are combining Airborne EM results with detailed 3D geological models to establish a much clearer picture of the spatial distribution of saline groundwater as well as distribution in the geological setting.

Subsequently, 3D variable-density groundwater and coupled salt transport models use these salinity data to make more accurate predictions of the possible effects of climate change, sea level rise and human activities on the availability of fresh groundwater resources. Adaptive strategies to limit the impact of negative future stresses will be more effective and cheaper. Incorporating all these different innovative techniques will, in the end, lead to more sustainable water management.

Partners

- TNO
- Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
- Aarhus Geophysics
- Fugro UK

Living and building in the delta
lack of space

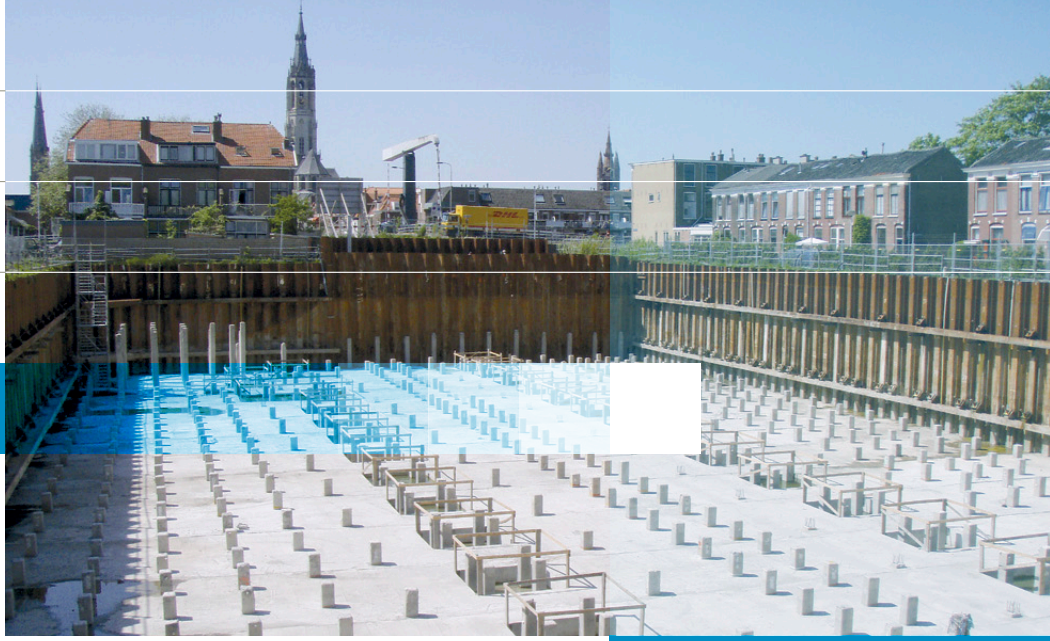
scope

Sustainable living in delta areas requires an understanding of building on and in soft soils. Underground construction, as well as onshore and nearshore transport infrastructure, contribute to a habitable and prosperous country. The challenges involved in foundation and hydraulic engineering are becoming more demanding for several reasons: increasing population density, mobility, and prosperity; the increasing shortage of space; the softer nature of the land that is still available; and public demand.

background

Pressure on the available space is increasing. Maintaining the quality of life and the habitat is becoming an ever more urgent problem both in the Netherlands and in comparable deltas throughout the world. 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, the increase in sea shipping transport and spatial demands in coastal areas are the driving force behind the expansion of harbours, 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. People are no longer willing to accept damage to their physical living environment, or nuisance caused by noise, vibration, dust or inaccessibility,



either for underground works or for roadworks. In addition, the construction sector has acquired a negative image in terms of cost control and planning delays. These problems are closely related to a lack of risk management, with the soil and subsurface being a major factor. Intelligent use of existing knowledge is a key factor in this respect.

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. Hydraulic engineering is a major Dutch export product, a fact that is also emphasised by the Netherlands Water Partnership.

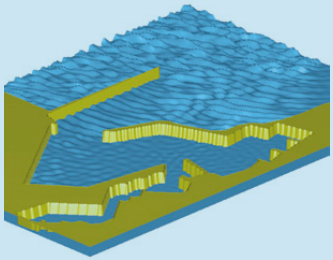
Seven road maps have been defined in this theme. H*arbours and waterways, Offshore developments* and *Hydraulic engineering focus* on the 'water' aspects in this theme. *Underground construction* and *Roads in the delta* concentrate on different types of linear infrastructure. *Adaptation of soil properties* focuses on the use of micro-organisms to improve soil (SmartSoils), and *DeltaBrain* looks for new ways of re-using existing knowledge by implementing modern ICT technology.

Contact

martijn.dejong@deltares.nl
+31 (0)88 335 85 96

arne.vanderhout@deltares.nl
+31 (0)88 335 80 08

Modelling an invisible wave problem

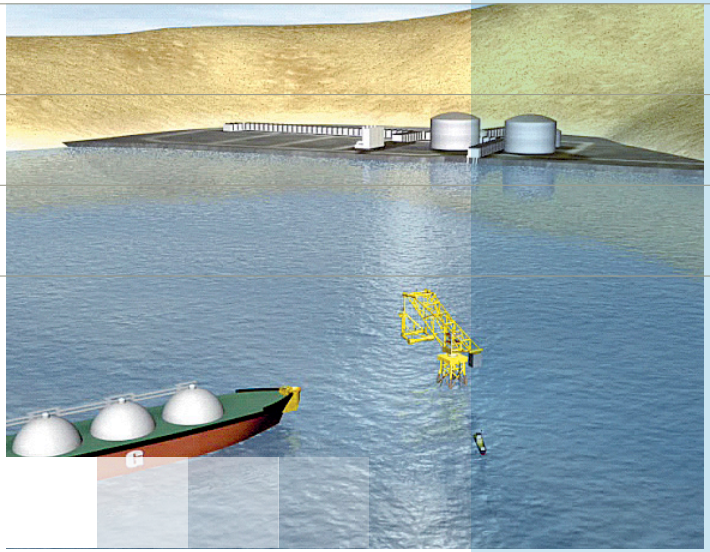


TRITON output

Wave conditions in shallow water can be very different from those in deeper water because of increased interactions between wave components, resulting in groups of waves at intervals of about 1-2 minutes. A long wave is generated underneath each group. These long waves have small amplitudes and are not therefore visible to the naked eye as the appearance of the sea is dominated by the shorter waves. Nevertheless, these long waves, which are also known as infragravity or low-frequency waves, can have a considerable impact.

Ships moored at nearshore facilities or inside ports are susceptible to waves in this period range. They can be moved excessively in a resonant response to the waves, resulting in unworkable situations and high downtimes. The Joint Industry Project (JIP) Hawal, (the sHAllow WAter Initiative) was therefore launched in 2005 with the aim of furthering our understanding of these long waves, including how they can be modelled and predicted. The follow-up project Hawall was launched recently to look at the remaining issues, with the aim of developing a complete and practical design methodology for mooring facilities in shallow water.

The JIP focuses on intermediate depths of about 15-50 m, which is shallow compared to offshore applications, but deep from the viewpoint of coastal engineering. This means that the application range of the wave models from coastal engineering needs to be extended towards these intermediate depths. The Boussinesq-type wave model TRITON computes the sea waves accurately, but it results in a considerable *underestimation* of the long waves in intermediate depths. Other models of this type have similar characteristics and limitations. As a result, a different



A nearshore LNG facility

type of model that describes the overall effect of the groups on the long waves only was considered and was found to produce accurate results for long waves. However, since this model does not calculate the sea waves in detail, it provides only part of the required design information.

After Hawal was finished, the TRITON model was extended within the framework of the Delft Cluster research programme in order to provide a more accurate description of long waves. In the present project, the extended model version was used to re-evaluate the use of TRITON to calculate long waves in intermediate depths. Unfortunately, the results showed that the extension of the model now resulted in an *overestimation* of the long waves. It proved necessary to scale the effect of the additional terms with a single constant factor. In this way, the extended model can produce accurate results for a wide range of depths (including intermediate depths) and wave conditions (short and long waves).

Further reading

De Jong, M.P.C. et al, *Evaluation of an extended operational Boussinesq-type wave model for calculating low-frequency waves in intermediate depths*, 30th Int Conf OMAE2011, Rotterdam, The Netherlands.

Partners

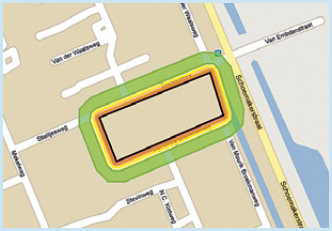
Group of 25 participants in Joint Industry Project

Contact

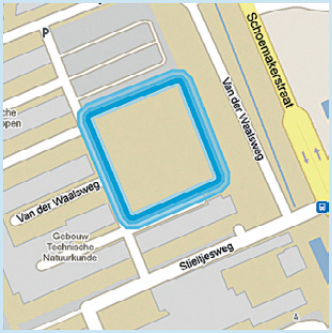
janneke.salemans@deltares.nl
+31 (0)88 335 73 65

hans.brinkman@deltares.nl
+31 (0)88 335 76 76

Impact of building pits in urban areas



Surface settlement around building pit



Prediction of vibration damage caused by installation of sheet piling wall

In densely populated areas, the available space for building projects is limited. The only available space is to be found by moving up (skyscrapers) or by moving down (underground buildings). Underground construction is often risky because of the close proximity of adjacent properties, specifically when they are monumental and vulnerable. An analysis of forty building pit incidents over the last 20 years revealed that 90% of the problems in building projects are not caused by a lack of knowledge, but by a lack of the right knowledge at the right location at the right time. Transfer of knowledge is therefore the key issue of this project.

Combining a number of available calculation and prediction models with experience databases in a "toolbox" makes it possible to implement underground projects with a better understanding of the risks and the impact on the surroundings. Risks are clearer in each project phase, and are traceable and transferable in between project phases. A picture of the risks helps decision-making during design.

The stakeholders for this toolbox vary from phase to phase. In the preliminary design phase, the local authorities, town planners and project developers can use the toolbox for a quick overview of the impact on the surroundings. When the real design starts the toolbox can be used by engineers and contractors for an overview of the geotechnical project risks. In the construction phase the toolbox can support contractors and supervisors.

A prediction tool for vibrations and settlement is interesting in the preliminary design phase. The toolbox uses Google Maps as the platform for geographical information. The application is linked to the DINO database for underground information. By drawing the contours of the planned building pit on its location in the Netherlands and entering the excavation depth, impact

contours are automatically constructed for surface settlement or vibratory damage. The contours are based on simple models by Peck (for surface settlement due to excavation) and SBR (for calculating vibration intensity). In this phase a simple sheet piling wall with one anchor point is assumed, for which surface settlements and vibrations are predicted. In the near future the prediction tool will be expanded to simple rotation and damage prediction assessments of the buildings next to the pit.

As a risk tool for use in the preliminary design and final design phase, a large number of risks associated with building pit elements have been included in an expert database. By making design decisions (like choices of sheet piling wall or retaining wall, and vibrated, pushed or hammered into the subsoil) one can easily establish an overview of the risks associated with this specific design.

Settlement of the surface outside the pit is caused not only by the excavation of a building pit, but also by densification of the soil induced by the vibratory installation and removal of the sheet piling wall. The model developed by Meijers (2007) has now been integrated in the DSheet piling design software of Delft Systems. This is the first step on the road to a comprehensive building pit design toolbox.

Further reading

Meijers, P. Tol, A.F. van, *Voorspelling maaiveldzakking door het in/ en uittrillen van damwanden* (In Dutch) , Geotechniek, July 2010, pp 40-45

Contact

frans.barends@deltares.nl
+31 (0)88 335 73 55

wouter.vanderstar@deltares.nl
+31 (0)88 335 72 69

Biogrout for undisturbed sampling

The present state of the art of dike safety assessment does not include an efficient method for appraising the likelihood of the liquefaction of loosely packed sands. As in many other deltas, loose sands are found quite regularly along the coasts and rivers of the Netherlands. Sometimes, expensive mitigation measures are taken to create a larger margin in dike safety, for example near the town of Dordrecht, but this is a strategy based on lack of knowledge and the urgency of the measures enjoys almost no support.

The liquefaction potential of a sand layer is mainly determined by its density and by the possibility that it really can flow when once fluidised. Current investigation techniques cannot measure local density accurately enough. Loose sand has no cohesion and falls apart when sampled; at more than 20%, there is therefore too much disturbance of the sample.

In the context of the Deltares Eureka! contest, a prize has been awarded to the idea of fixing the material with Biogrout. The Biogrout process had been under study for several years and involves the injection of specific bacteria and nutrients into a soil layer. The bacteria generate calcite crystals as a bonding agent between the grains, replicating the natural formation of sandstone. The feasibility of fixing the local sand density with a "light" Biogrout treatment and retrieving an undisturbed sample was investigated. Proper Biogrout cementation is critical. It should not be excessive, making sampling impossible, or inadequate to preserve the matrix structure of the sand during sampling. The study took a detailed look at the Biogrout reinforcement process and promising sampling methods.

The clod method

A field situation was modelled in the lab in a container with loose sand with a uniform relative density of 26%. Bacteria and nutrients (urea) and calcium were washed through the sand. Two sampling methods were tested: the ring and the clod method. The ring is essentially a thin walled fixed-volume cylinder for taking samples; the density follows from the weight of the sampled material. The clod method collects the spontaneously formed clods of soil and measures external volume and weight. With both methods, an accuracy of better than 1% has been achieved, which is exceptionally good for sampling loose sand. For a field test, the clod method is the more appealing option. The final goal is the development of a robust in situ sampling technique suitable for practice.

This idea won a prize in the Deltares Eureka! contest 2010

Contact

victor.hopman@deltares.nl
+31 (0)6 5131 8686

Construction screening with vibrations and fingerprinting

After serious incidents in Amsterdam and Rotterdam, there has been an increased reluctance to use diaphragm walls in deep excavations in the Netherlands. In densely populated areas, the risk of unexpected leaks and the resulting subsidence are not acceptable. As there is a clear need to reduce uncertainty about the quality of construction elements formed in situ, a research programme was initiated to determine whether points where there is a high leak risk can be detected before excavation takes place.

A combination of innovative methods was used to check quality at the weakest points: the joints between the successively constructed panels of the wall. Bentonite inclusions, which are known to be potential weak spots, will not be found in a traditional pumping test because they have a high hydraulic resistance, but they may collapse when subjected to mechanical stress during and after the excavation. Temperature 'fingerprints' are obtained by hundreds of meters of fibre-optic cables mounted in the wall over the length of the joints. They monitor the replacement of the bentonite by the concrete and measure the heat development of the hardening concrete. Afterwards, weak spots can be located using the sonic cross-hole technique.

The research started at the same time as a laboratory test with blocks and a series of tests on the construction site of the "Kruisplein" underground parking facility in Rotterdam. In the laboratory test, the temperature measurements were difficult to interpret, partly due to the rapid pouring of the concrete and partly because of the spatial resolution of the temperature measurement (1 m). The sonic method is commercially available for testing the integrity of large diameter bored piles but it was not known what influence the joint would have on the signal

transmission. In a sonic cross-hole measurement, the source/receiver positions were changed to perform 2D tomography. With information about both the arrival time and damping, it proved possible to estimate the volume of the one anomaly that had been introduced in the test area.

In the field test, the 'fingerprints' clearly showed the rising concrete level in the trench on the basis of the temperature difference between the concrete and the bentonite. Anomalies in the hardening heat were not detected in any of the joints. After hardening, a simple 'horizontal' measurement was conducted, in which both the source and receiver were on the same level and were pulled up simultaneously. An anomaly was found in one joint. At the depth at which this anomaly was found, clayish layers are expected outside the excavation. No further measures are taken to prevent leakage as the soil itself functions as a barrier. As excavation is still in progress, the size of the anomaly has not yet been verified.

partners

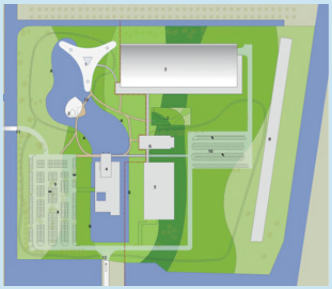
- TU Delft
- several municipalities
- 10 private parties

Contact

mieke.ketelaars@deltares.nl
+31 (0)88 335 80 14

victor.beumer@deltares.nl
+31 (0)88 335 77 86

Revitalisation of the Deltares campus using Eco Dynamic Design

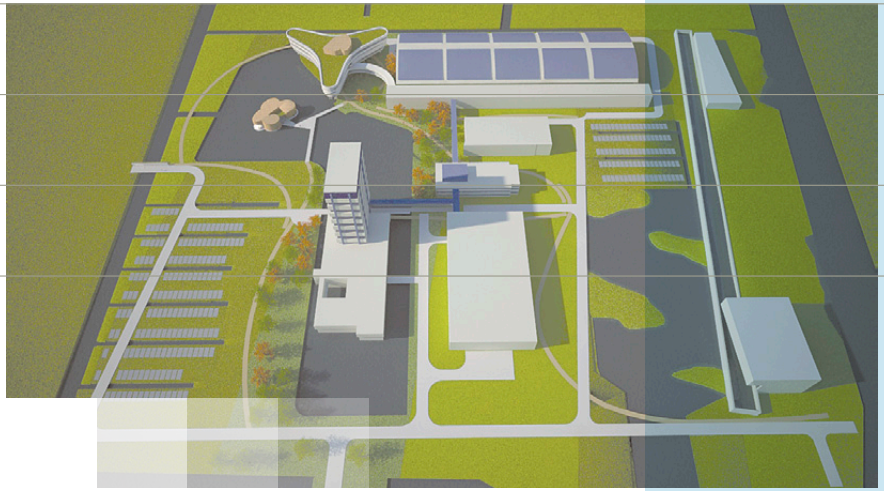


Eco-Dynamic Design Deltares campus

Over the next few years, Deltares will be revitalising its Delft campus. A new office block and pavilion will be built, and outdated testing facilities will be demolished and replaced. The new campus is intended to reflect the mission of Deltares: enabling sustainable delta life. This challenge raises questions about priorities for sustainability themes, identifying site-specific opportunities, estimating the costs and benefits of sustainable solutions, and making guidelines and specifications for architect and contractors. Deltares has applied its own Eco Dynamic Design (EDD) method to turning its mission into reality.

Rather than applying standard solutions and rating systems, Eco Dynamic Design employs the site-specific possibilities to create added value. Design with EDD links the development of a site or infrastructure to the specifics of the location, generating positive effects on ecological values, soil, water and air quality, possibilities for recreation, options for future use and experience.

A team comprising EDD experts, Deltares employees, the architect, contractors and local environmental groups made the design. The team identified the regional and local characteristics and urgent issues of the stakeholders, and analysed how the design of the campus could make a positive contribution to these issues. The team selected, as the main themes, Habitat creation, Design for re-use & Energy generation, providing Connectivity and Story-telling, demonstrating the Deltares mission 'Enabling Delta Life'.



Habitat creation will focus on characteristic species such as pike, barn owl and martin. The construction of ecological banks and puddles for amphibians will not only contribute to a healthier pike population, but also to a more balanced regional ecosystem. Telling the story of "Enabling Delta Life" is realised by using the campus as a testing ground for innovative technology and concepts. Connecting natural areas surrounding the campus to the ecological banks increases the chemical and ecological water quality in a wider area. The aim of design for re-use is to conserve the soil and groundwater system and to use local materials. Concrete waste from the demolition of the old testing facilities can be used in new roads and buildings; old walking bridges may be re-used for parking bicycles.

Local environmental groups were very happy with their extensive involvement and the final results. EDD has established a positive attitude among the local stakeholders towards the campus revitalisation. This is another benefit of EDD that may save a lot of time in the development of a site or infrastructure, since future conflicts are avoided.

Further reading

Sustainable infrastructure, from ambitions to realization.
Proc 24th PIARC World Road Congress, Mexico City, 2011

Partners

- EDD experts
- Deltares employees
- architect
- contractors and local environmental groups

Availability of water and soil systems

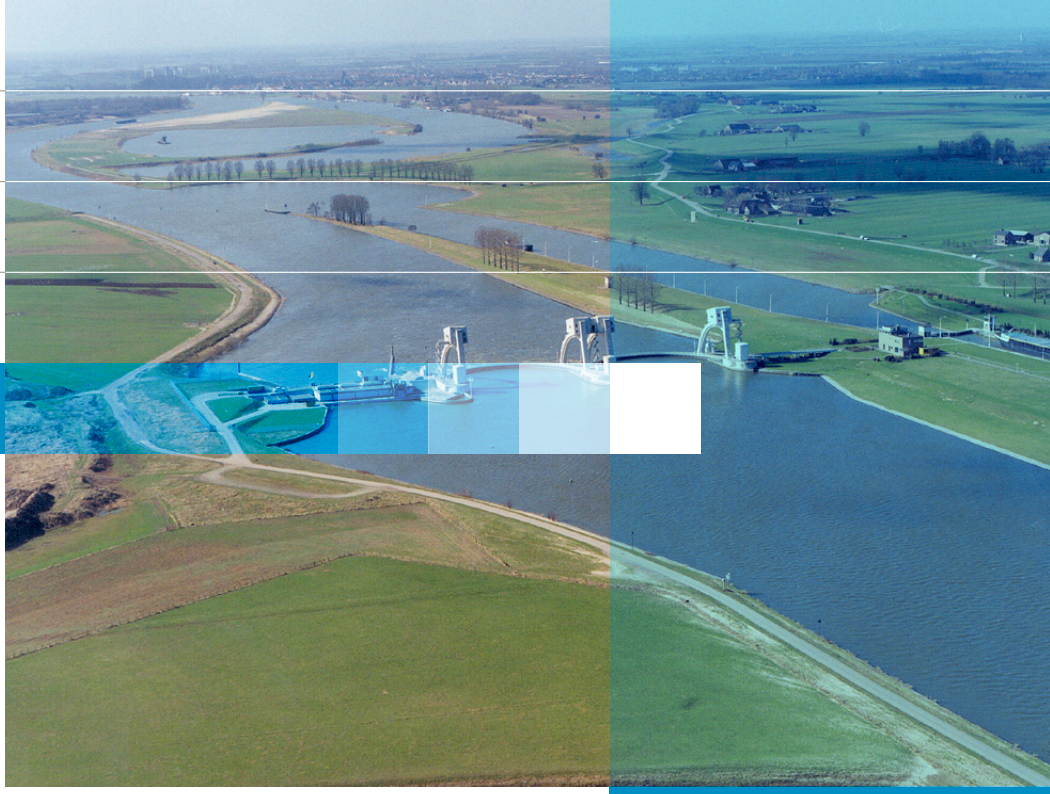
scope

Water management means having enough supplies of clean water, being protected against excess water, and also coping with drought conditions. Subsoil management includes heat and cold storage in the soil, as well as mining sand and clay as a resource. Politicians and managers can be provided with optimal support by combining technical expertise and risk information with insights from the exact and social sciences.

background

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 correspondingly 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. Technical and scientific knowledge is not enough here. Good communications with water managers are at least as important. 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 road maps in this theme cover water and soil: *Basin scale water management, Water shortage and salinisation in rural areas, Water nuisance and water use in de city, Sustainable energy from water and subsoil* and *Sustainable mining as a subsoil service.*

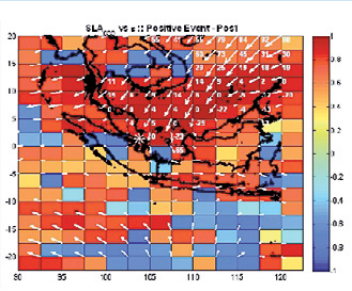
Contact

herman.gerritsen@deltares.nl
+31 (0)88 335 84 70

MustHaveBox

Understanding flows in SE Asian waters

In 2006 / 2007, Deltares initiated the two long-term MustHaveBox studies with the aim of improving understanding of, and modelling, the water level and current anomalies in Singapore's regional waters. The area is a key navigation corridor for marine transport from Europe and the Near East to countries like China and Japan, while Singapore itself is one of the world's largest navigational and industrial hubs. Improved forecasting of the regions' water levels and currents, in particular the occurrence of non-tidal anomalies, is therefore of great economic value. The ultimate goal of the project is to create the "MustHaveBox", a "TomTom" type navigation system for marine traffic.

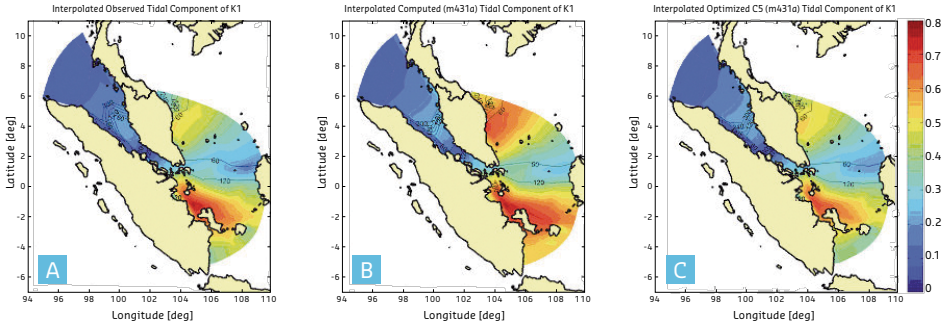


Correlation of water level anomalies at Singapore with wind stress (colour) and direction (arrow); numbers in the cells denote time lags for maximum correlation (NE monsoon situation)

The studies initially concentrated on the analysis of near-coast water level and current observations, open-water satellite altimetry data, and wind and pressure fields. This established the basis for a much better understanding of tidal interactions on a larger scale, and the different mechanisms that cause the anomalies in water levels and currents.

First, there is the monsoon, which leads to basin-scale sloshing in the water level, with typical annual and semi-annual periodicities. While the monsoon is clearly a meteorological phenomenon, the local water level variation can also be interpreted as a tidal phenomenon. This interpretation is useful when assessing the average annual cycle of water level variation in open water, as derived from altimetry.

A second mechanism is tropical-cyclone-induced surges, with time scales of days to well over a week. Correlating historic time series of water level anomalies at Singapore with time series for wind stress in a 35 by 35 degree region around Singapore showed



Spatial distribution of K1 tidal constants: (A) interpolated observed, (B) interpolated model results before model analysis, (C) interpolated model results after model analysis. Colours denote magnitude of the co-amplitude (m), contour lines the co-phase (degree)

that these anomalies are triggered by cyclones originating in the open South China Sea, which then move in a southwesterly direction.

A further research element involved extracting information from time series of recent water level observations to improve short-term forecasts of non-tidal contributions for time scales of up to four days. Various sophisticated filtering techniques, artificial neural networks, wavelet analysis, phase space embedding and genetic programming all prove useful in improving numerical flow model results.

A third focus of the studies is the deterministic modelling of the water levels and flows by hydrodynamic models, taking into account co-oscillating tide forcing from the Indian and Pacific Oceans, later combined with monsoon effects and storm events. Two existing models were applied: SRM-c for Singapore regional waters and SCSX for modelling the flows in the wider South China Sea and Indonesian waters. The data assimilation environment OpenDA, launched in 2010 as open source by Deltares, TUDelft and VORtech, proved a successful tool in model sensitivity analysis and model improvement.

Further reading

Gerritsen, Herman et al, *MUSTHAVEBOX - Analysis and prediction of sea level anomalies and associated currents in Singapore and Malacca Straits*. Proc. 8th Int. Conf on Hydroinformatics, Concepcion, Chile, 12-16 January 2009, paper 188a163,

Partners

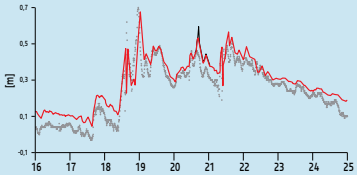
- BMT ARGOSS
- Singapore Delft Water Alliance (SDWA)

Contact

martin.verlaan@deltares.nl
+31 (0)88 335 79 56

OpenDA

an open-source software toolbox for data assimilation

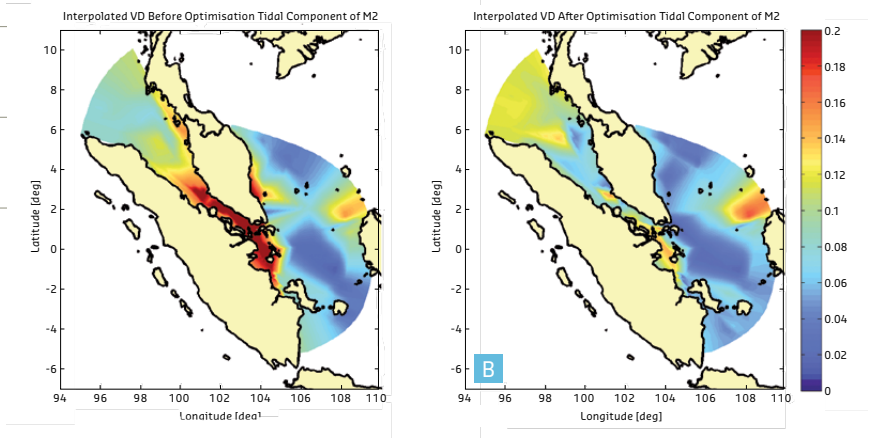


Water level Ramspolbrug with and without closure of Balgstuw barrier at January 20, 2007. Grey dots: measured; red line calculated with IJssel Vecht Delta model, black line with closure of Balgstuw

Data assimilation is involved more and more in the modelling of geophysical processes. The term is used to describe a range of diverse mathematical techniques for the smart combination of model results and data to analyse and improve the quality of model results in a quantified, objective way. Examples are model calibration (in other words, the optimisation of model parameters) and model forecasting through filtering (in other words, enhancing the model forecast or model output). Structured data assimilation of this kind is often required if one wants to control and optimise the quality of modelling with highly complex model systems. Simply stated, data assimilation pulls the computer model results close to the available observations in a user-controlled way. This means that the model achieves a better match with the actual situation and consequently produces better predictions than it would without data assimilation.

Developing data assimilation functionality for a model is the work of specialists. Data assimilation concepts and software are often very complex. A significant effort, and therefore a major investment, are required. Errors are easily made in implementing the software and, when they are, results will be disappointing or downright wrong. In 2007 Deltares (then Delft Hydraulics), TU Delft and VORtech combined their individual research efforts on data assimilation to create the assimilation environment "OpenDA". Its data assimilation modules are generic and separate, and are not interwoven with the models that describe the processes.

The OpenDA data assimilation environment solves most of the problems described above relating to development time, investment and complexity by delivering a generic set of building blocks that allow the implementation of data assimilation for



M2 tide in the Singapore Regional Model domain showing (A) interpolated model results before optimisation, (B) interpolated model results after optimisation

an arbitrary model with relatively little effort. The building blocks can be reused again and again and are tested with each new application. Over time, therefore, they will be largely error-free. Furthermore, the building blocks are optimised for high-performance computing. That is important because data assimilation tends to involve a large number of computations.

In May 2010, Deltares, VORtech and TUDelft / EWI officially launched OpenDA as an open source software environment for the easy application of data assimilation in models describing geophysical processes. The system, documentation, tutorials and example test cases for Windows and LINUX platforms can be downloaded from www.openda.org. Increasing OpenDA use by developers and users will lead to additional testing and more functionality, which is beneficial to a community of users extending well beyond the three association partner institutes.

OpenDA interfaces are already in place for many major systems and most functionality is now also available in FEWS. Examples of applications are the calibration of the IJsselmeer Vecht Delta model (in WAQUA), the calibration of the tidal model for Malacca Strait and Singapore waters (in Delft3D-Flow) and calibration of the wave model for SBW Waddenzee (in SWAN).

Further reading

www.openda.org.

Partners

- VORtech
- TU Delft
- SDWA

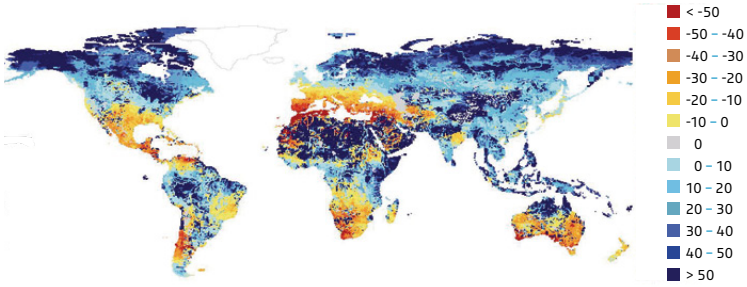
Contact

frederiek.spernaweiland@deltares.nl
+31 (0)88 335 82 30

A global assessment of climate change induces hydrological changes

Climate change has significant effects on global runoff regimes, affecting water availability for agriculture and ecosystems. In order to anticipate these changes, reliable assessments of the hydrological effects of climate change, including information about uncertainties, are needed. Studies investigating the hydrological effects of climate change are often based on results from General Circulation Models (GCMs). However, large biases resulting from climate observations are present in GCM data, especially for precipitation. As a result, hydrological changes derived from GCMs are rather uncertain and can be contradictory when being derived from other GCMs.

In this study we assessed the effects of climate change on hydrological regimes and the associated uncertainties. Meteorological data from twelve GCMs for several IPCC emission scenarios were used for forcing the global hydrological model PCR-GLOBWB developed at Utrecht University. We made calculations to determine where in the world changes in hydrology are projected that are significant and consistent in the ensemble of twelve GCMs.



Average percentage discharge change (%) for the GCM ensemble for the emission scenario A1B by 2100

This study makes two new steps: firstly, the integration of the significance of change in discharges for both the individual GCMs and the ensemble of GCMs, significance being calculated relative to the ensemble uncertainty; secondly, the consistency of the changes projected by the individual GCMs with the projected change of the ensemble.

By calculating the significance of change for the GCMs individually, it is possible to denote regions with notable change, despite the uncertainty in and deviations between GCMs. The resulting consistency map shows for each grid cell how many models produced the same direction of change and where, consequently, there is a high likelihood of hydrological change. This represents a potential step forward in dealing with climate model uncertainty.

The differences between the emission scenarios appear to be small. However, the discharge results for the different GCMs diverge widely. It is therefore valuable to analyse the changes obtained from an *ensemble* of GCMs. Despite discrepancies amongst GCMs, a number of consistent results have been found.

Ongoing research is assessing the value of the direct use of GCM runoff fields (instead of using temperature and precipitation from GCMs as input for a hydrological model) for estimating hydrological changes.

Further reading

Sperna Weiland, F.C. et al., 2010: *Global pattern of change in runoff regimes for 2100.* Submitted to Climatic Change

Partner

- Knowledge for Climate

Contact

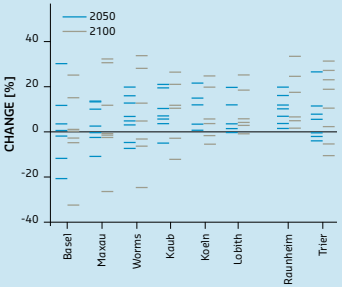
otto.dekeizer@deltares.nl
+31 (0)88 335 76 57

Rheinblick 2050

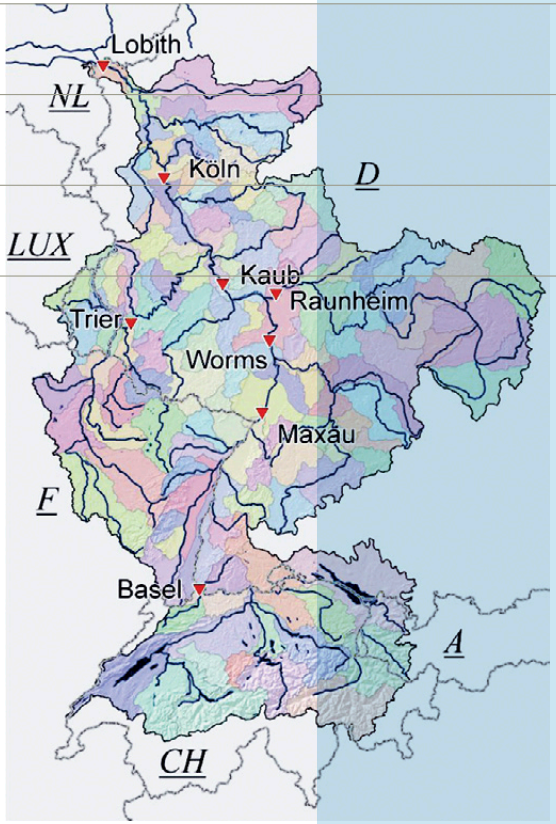
Climate change leads to modified hydro-meteorological regimes that influence the discharge behaviour of rivers. The impact on water systems varies according to the sensitivity of the systems and the climate-change-vulnerability of the ecology, economy, infrastructure, transport, energy production and water management. Decision-makers in these contexts therefore need adequate information (i.e. "informed options") about potential future conditions to develop adaptation strategies so that they can minimise the adverse effects of climate change.

In the context of the Rhine River Basin, the International Commission for the Hydrology of the Rhine Basin (CHR) and the International Commission for the Protection of the Rhine (ICPR) initiated the Rheinblick2050 project. A unique basin-wide collaboration was established involving climate and water research institutes from all riparian countries. The main research question of the RheinBlick2050 project is: What are the impacts of future climate change on the discharge of the Rhine River and its major tributaries?

The experiment design uses a data-synthesis, multi-model approach. A selected ensemble of 20 regional climate simulations is used as forcing data for the hydrological model with a daily temporal resolution over the catchments of the Rhine River. A model chain for climate impact assessments forms the core of the study: greenhouse gas emission scenarios force the global climate models, the data from which is used as input for some sort of regionalisation (dynamical or statistical downscaling, mainly from the EU FP6 Ensembles project); what follows are the subsequent processing steps (incl. bias correction), hydrological model runs and finally the derivation of impact diagnostics.



Projected relative changes for 100-year flood



River Rhine basin with catchment areas and gauging stations

The future changes in mean discharge, low flow and high flow (including bandwidths) are being investigated for eight selected gauging stations along the Rhine River down to Lobith, as well as the Main and Moselle river tributaries. These analyses are coordinated with the requirements of the potential users and stakeholders from government agencies. Near and distant future scenario horizons (2021 - 2050 and 2071 – 2100) are being considered.

The mean hydrological winter discharge tends to increase. For the summer, an opposite tendency is found for the distant future. With respect to low flow, we see no strong development in the near future since there is no clear tendency in the summer for most ensemble members. In the distant future, there is a tendency towards decreased low flow discharges.

For high-flow statistics a non-linear bias correction has been applied that takes into account the fact that flood events also depend on extreme daily and multi-day precipitation and not only on the mean precipitation. A weather generator has been applied to generate long time series of forcing data. For flow regimes characterised by winter high flows, there is an overall tendency towards increased high flows.

Further reading

Görgen, K. et al (2010), *Assessment of Climate Change Impacts on Discharge in the Rhine River Basin*, www.chr-khr.org/files/CHR_I-23.pdf

Partners

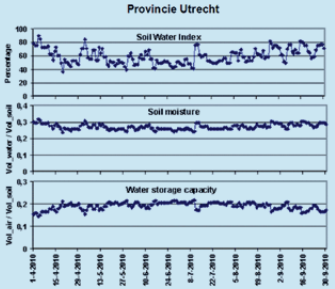
Rijkswaterstaat Waterdienst

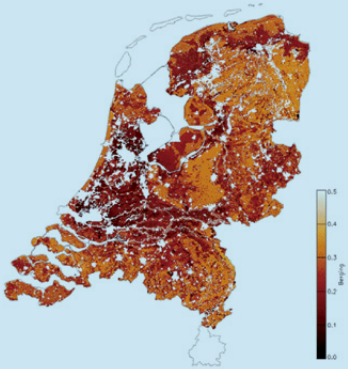
Contact

marco.kleuskens@deltares.nl
+31 (0)88 335 78 55

remko.delange@neo.nl
+31 (0)33 463 74 33

Water storage capacity of Dutch soil monitored from space



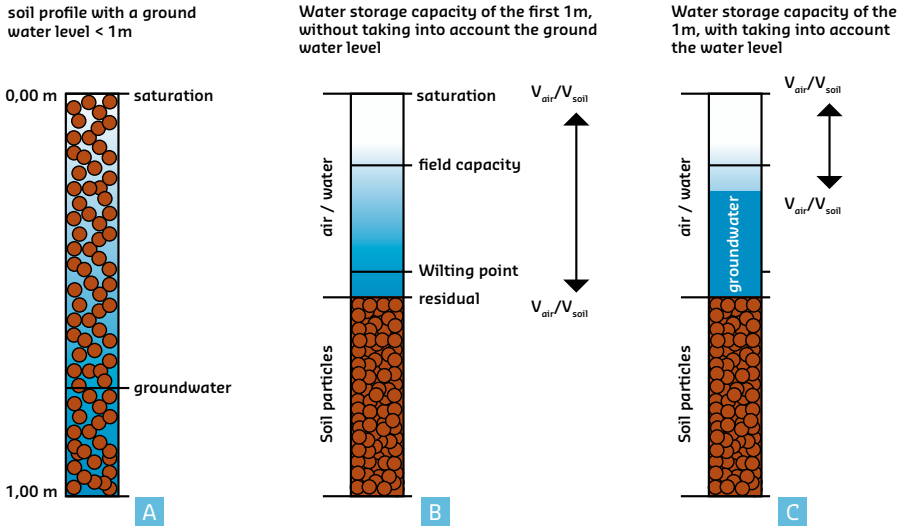


Soil water storage capacity in 250 x 250 m cells

Soil moisture is an essential climate variable (ECV). It is valuable for obtaining more information about crop yield. In the Netherlands, where 55% of the country is below the mean sea level and contained by dikes, it also plays a major role in dike stability and soil subsidence. Drought can destabilise dikes and lead to more soil subsidence, exacerbating the risk of flooding. Although soil moisture is an ECV, experience and interviews in the project have indicated that water managers tend to think more in terms of water storage or evaporation than in terms of soil moisture.

In 2010, Deltares and NEO (Netherlands Geomatics and Earth Observation) performed joint research to further our understanding of satellite monitoring of the water storage capacity of the Dutch soil. The project combined NEO's DRYMON method and the incorporation of groundwater and soil data from the Netherlands Hydrological Instruments (NHI). It produced, for each Dutch province, real-time and online output showing average soil water storage, exporting the data to a web page.

The method is unique in two ways. Firstly, by inputting groundwater level information from NHI into areas with a groundwater level less than 1 m below surface, DRYMON soil moisture values are calibrated more accurately. Secondly, the soil moisture values monitored with the DRYMON method are converted to values indicating soil water storage capacity using NHI soil information and the NHI information about groundwater levels. The DRYMON method uses daily satellite sensor data from the MetOp satellites (EUMETSAT) with a low spatial resolution (25 km x 25 km). By combining this information with NHI cells, the water storage data can be delivered on demand in near-real time in 250 m x 250 m cells. However, to avoid oversampling



errors, it was decided in this project to average the DRYMON cells at the province level. The near-real-time output can be found on the web: http://drymon.biz/artikelen/artikel62.html.

The DRYMON monitoring method can deliver soil water storage information on an almost daily basis, making it very useful for comparison with existing operational information from water managers. In addition, data can be directly related to rainfall forecast. Recommendations for further research are assimilation with hydrological models and the incorporation of capillary rise and root zone in the DRYMON algorithm.

It should be noted that DRYMON values are unreliable in the winter, since satellite sensor restrictions apply due to frozen ground and snow cover.

Further reading:
Westerhoff, R. et al, *Radarsatelliet-informatie voor Nederlands water-beheer,* Stromingen, maart 2011 (in Dutch)

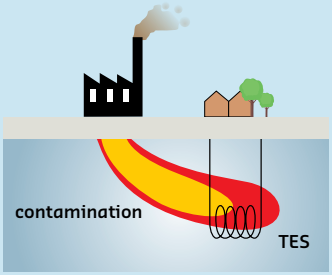
Acknowledgements:
This project was funded by the Netherlands Space Office. Data used was ASCAT data (EUMETSAT) and Envisat ASAR data (data provided by the European Space Agency). Valuable information was supplied by RWS Centre for Water Management, Alterra, KNMI and Hoogheemraadschap De Stichtse Rijnlanden.

Contact

hans.gehrels@deltares.nl
+31 (0)88 335 78 23

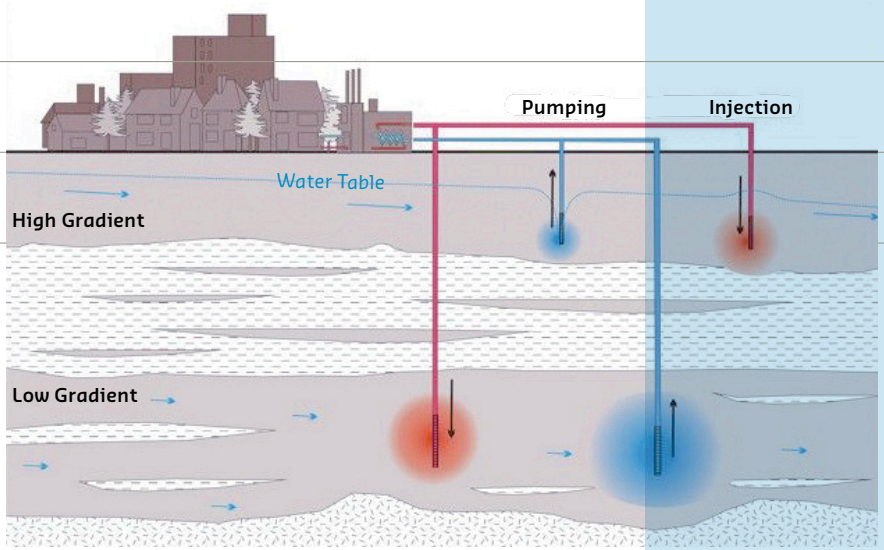
More with soil energy

The project 'More with soil energy' targets the utilisation and the protection of the subsurface for the purposes of thermal energy storage (TES). Aquifer and borehole thermal energy storage can considerably reduce energy consumption for heating and cooling buildings and greenhouses. For the purposes of this technology, the subsurface is warmed up or cooled, depending on the season, and the energy can then be recovered in another season. Given the rapid proliferation of TES installations in the Netherlands, questions arise about the impacts and the rising need for the proper utilisation of the subsurface. Stakeholders have joined forces for this research project. They include all government levels, energy companies and drinking water suppliers.



TES installations can affect existing groundwater pollution and they may even be helpful for soil remediation. The combination of TES and remediation has not often been put into practice, so many questions remain. This project aims to define the conditions in which a combination of TES and remediation can be beneficial. It is not only remediation that can be combined with TES; other combinations and functions may also be possible. TES might be combined with thermal energy reclamation from the surface water, residual heat from industrial processes or the desalinisation of process water. This project identifies potentially interesting combinations and elaborates some of them in greater detail.

The existing literature contains information about the effects of TES on the groundwater system, for instance groundwater flow, salt intrusion, chemical balances and the soil ecology. For the possible benefits and disadvantages of the combination of TES



and remediation, relevant topics are the effect of a temperature increase on the growth rate of bacteria that can decompose organic pollutants, the risk of well clogging and the potential of different remediation techniques in terms of combination with TES.

Many TES installations have been monitored for effects in the surroundings during operations. However, no clear view has emerged about their long-term effects and the importance of these effects on the soil (ecology, buffer capacity) or other (subsurface) functions nearby. The aim of the measurements conducted at several test sites is to establish a more coherent view about effects and their causes. Some of these measurements can be used for creating models or improving existing ones, and be interpreted for the purposes of arriving at more general conclusions.

further reading

www.meermetbodemenergie.nl

Partners

- IF Technology, Bioclear
- Wageningen University.

Contact

dimmie.hendriks@deltares.nl
+31 (0)88 335 75 44

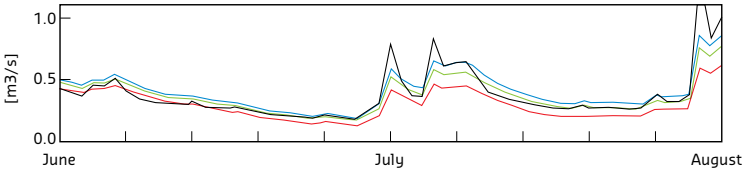
marijn.kuijper@deltares.nl
+31 (0)88 335 78 60

Low flow and ecological status in Merkske

The European Water Framework Directive (WFD) explicitly assumes that good groundwater status is required to maintain good surface water status and to achieve the environmental objectives for surface water bodies. Research was therefore initiated to develop a methodology to determine the effect of changes in the groundwater system on surface water and on the ecological status of streams. The research also includes the extent to which surface water and ecology are affected by human impact on the groundwater system, now and in the future.

This was done through a pilot study in the Merkske catchment. Merkske is a permanent, slow-moving headwater on sand. Low Merkske flows are largely determined by the seepage flow from the deep groundwater towards the stream. A system of tertiary water courses in the area provides drainage for agricultural purposes. In addition, there is water extraction for drinking water and industry and, in summer, groundwater is extracted for irrigation.

A groundwater model was used to compare the undisturbed state of the catchment with the current situation, and a number of scenarios were applied in which the effects of climate change were included. Moreover, an investigation took place to see whether the "environmental flow needs" in relation to the low flows of the stream are currently being disturbed by human



Summer discharge low flows in the current situation (green) and some scenarios (black, red and blue)

't Merkske

interventions or whether they will be unaffected by future changes in water management or climate change. In other words: are the low flows of the Merkske lowered to such an extent by drainage, withdrawals and climate change that the flow of the stream will no longer meet the ecological objectives?

It would appear that, in this catchment, the presence of drainage systems has had a predominant impact on the status of the groundwater system and on low flows (25-35% reduction). The total annual groundwater extraction causes a reduction of low flows of approximately 10% throughout the summer. The irrigation withdrawals cause about half of this reduction. Since the withdrawal capacity in this catchment is low compared to other areas in Northern Brabant, even higher impacts can be expected in other areas. Climate change may result in a reduction of about 45% in low flows in 2100 compared to the current situation.

Despite the current and future interventions and changes in the catchment, model calculations show that the flows in the main channel of the Merkske will stay above the minimum low flows indicated as the "environmental flow needs" of the stream. As a result, the ecological objectives are not yet under threat. More upstream, however, in the secondary and tertiary river reaches, current low flows are much closer to the environmentally indicated limits. An increase in withdrawal capacity, possibly in conjunction with climate change, will most probably lead to lower flow velocity and reduced water flow, resulting in a situation in which the ecological objectives can no longer be met.

Further reading

Hendriks D.M.D. and R. van Ek (2010) *Naar een (KRW-)methodiek voor het bepalen van de kwantitatieve interactie tussen grondwater en oppervlaktewater.* Case-studie 't Merkske (in Dutch)

Contact

dimmie.hendriks@deltares.nl
+31 (0)88 335 78 44

joachim.rozemeijer@deltares.nl
+31 (0)88 335 71 83

Dynamics in groundwater and surface water quality

Freely discharging lowland catchments are characterised by a system of discharging streams and ditches that expands and contracts strongly on a seasonal basis. This rapidly changing active channel network means that discharge and solute transport cannot be modelled using a single characteristic travel path, travel time distribution, unit hydrograph, or linear reservoir.

A systematic spatial averaging approach to derive catchment-scale storage and discharge from point-scale water balances was developed. The effects of spatial heterogeneity in soil properties, vegetation, and drainage network are described by a relation between groundwater storage and the spatial probability distribution of groundwater depths with measurable parameters. The model describes how, in lowland catchments, the catchment-scale flux from groundwater to surface water through various flow routes is affected by a changing active channel network, the unsaturated zone and surface ponding. Observations of groundwater levels and the catchment discharge of a 6.6 km^2 Dutch watershed (the Hupsel Brook catchment) were used in combination with a high-resolution spatially distributed hydrological model to test the model approach. The model improves the monitoring efficiency of groundwater-surface water interactions.

The lumped model approach based on groundwater distribution depth and the relation between stream concentration and travel time distribution dynamics was applied to assess the value of discharge and groundwater level measurements at various scales in the same research area ("nested scale") to predict catchment-scale discharge and nitrate loads. The estimated contribution of tube drain effluent (a dominant source for nitrates) was larger at the field-site scale (76–79%) than at the catchment scale

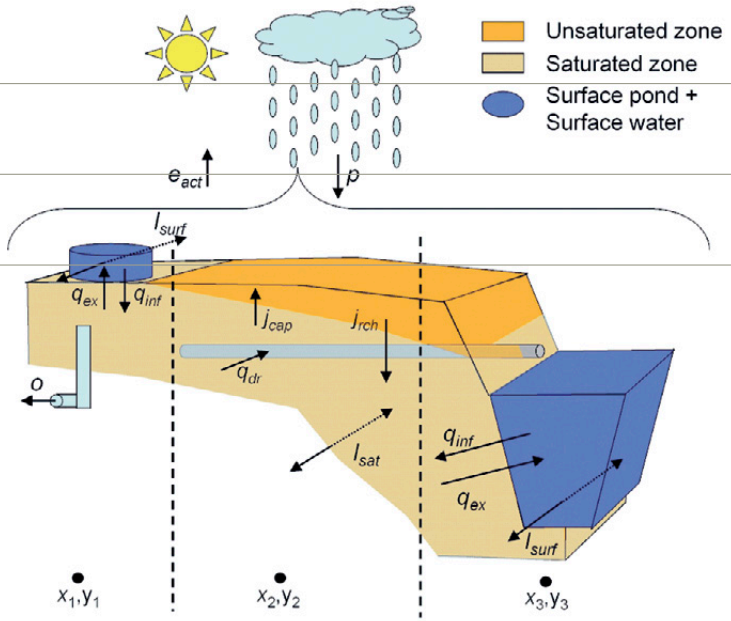


Diagram showing the lumped model concept

(25–61%). These results were validated by demonstrating that a model conditioned by nested-scale measurements simulates nitrate loads and predicts extreme discharges during validation periods better than a model conditioned by catchment discharge only.

Load estimates for NO_3 and P in surface waters were improved by describing the concentration response to rainfall events. Using semi-continuous on-site equipment, concentrations were measured from June 2007 to July 2008, and the concentration responses to rainfall events with a wide range in antecedent conditions and rainfall durations and intensities were recorded. Through sequential linear multiple regression analysis, the NO_3- and P-event responses were successfully linked to high-frequency records of precipitation, discharge, and groundwater levels. Regression models were used to reconstruct concentration patterns between low-frequency water quality measurements. These results demonstrate the value of commonly available precipitation, discharge, and groundwater level data for the interpretation of water quality measurements for improving load estimates from low-frequency concentration data.

Further reading

Velde, Y. van der. *Dynamics in groundwater and surface water quality: from field-scale processes to catchment-scale models*, PhD thesis Wageningen UR, 2011

Partners

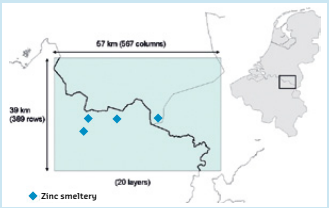
- Wageningen University and Research Centre

Contact

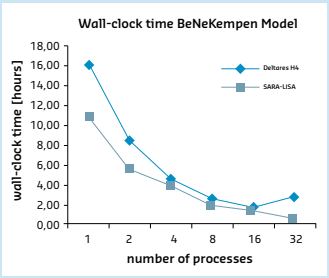
jarno.verkaik@deltares.nl
+31(0)88 335 71 63

jasper.griffioen@deltares.nl
+31(0)88 335 79 29

Massively parallel processing with MT3DMS for modelling groundwater transport



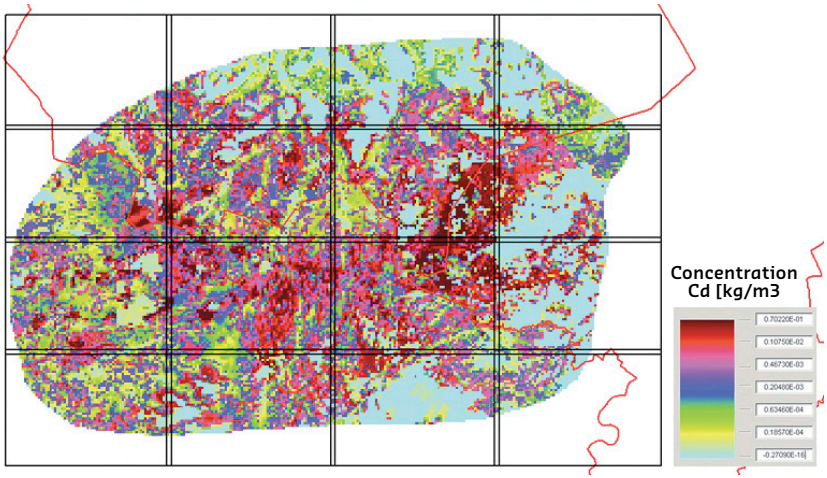
The area of interest and model sizes for the BeNeKempen model



Wall-clock times for SARA-/LISA cluster and Deltares H4 cluster

Preserving good groundwater and surface water quality is of major importance for water supplies, agriculture, and the environment. Groundwater and surface water bodies that provide us with clean water are threatened by a large range of contaminants such as nutrients, pesticides, or heavy metals. Several national and international policy programmes are in place to prevent that happening, examples being the Water Framework Directive, WB21, and Natura2000. In order to help decision-makers, accurate and fast simulation models are required to predict contaminant transport. This involves very detailed models, resulting in computing times that are, inherently, very long.

MT3DMS is a widely-used public domain code for modelling contaminant transport in groundwater. Over the past two decades, a large number of MT3DMS transport models have been built at Deltares. During that time, they have become more and more detailed, requiring more and more computing time. To speed up MT3DMS, a distributed memory parallelisation approach has been implemented in this project, allowing the code to run on high-performance computers in a massively parallel way, i.e. using a very large number of processors. In this approach the grid is partitioned into slightly overlapping blocks that are distributed equally over the processors. Each processor computes concentrations for its own block only, exchanges concentrations with neighbouring processors and writes its results to a separate file. Communication between processors is regulated with the widely used Message Passing Interface library. The TVD scheme is used to compute the advection part of the contaminant flow; the implicit solver in MT3DMS, the "GCG solver", was fully parallelised to compute the dispersion, sink/source and chemical reactions. Users now



have the alternative of selecting parallel solvers from the PETSc library (http://www.mcs.anl.gov/petsc). In terms of software, two new packages were added to the MT3DMS code: the MPP package (massively parallel processing) and the PET package (interface to PETSc library).

The performance of the parallel code was assessed for a large model developed for simulating groundwater transport of cadmium and zinc originating from historical emissions of four zinc smelters in the vicinity of the Dutch-Belgian border. The model consists of about 4.4 million grid cells and has a simulation period of 90 years. A speed-up of more than a factor 20 was measured with 32 processors on the Dutch national computer cluster SARA-LISA, reducing the computing time from 10 hours to 30 minutes. This shows that the parallel MT3DMS code can significantly reduce large computing times. Moreover, it is important to stress that our approach does not involve any loss of accuracy in results.

Acknowledgement
This work was sponsored by Stichting Nationale Computerfaciliteiten for the use of supercomputer facilities, with financial support from NWO.

Colofon

Editor
Jurjen van Deen

Image editor
Thomas van der Linden

English Text Advice
Pete Thomas, Alkmaar

Design
Martin van Schie

Printing
3L Drukkerij BV, Rotterdam

Deltares

PO Box 177
2600 MH Delft
The Netherlands
T+31 (0)88 335 82 73
info@deltares.nl
www.deltares.nl