



Land subsidence

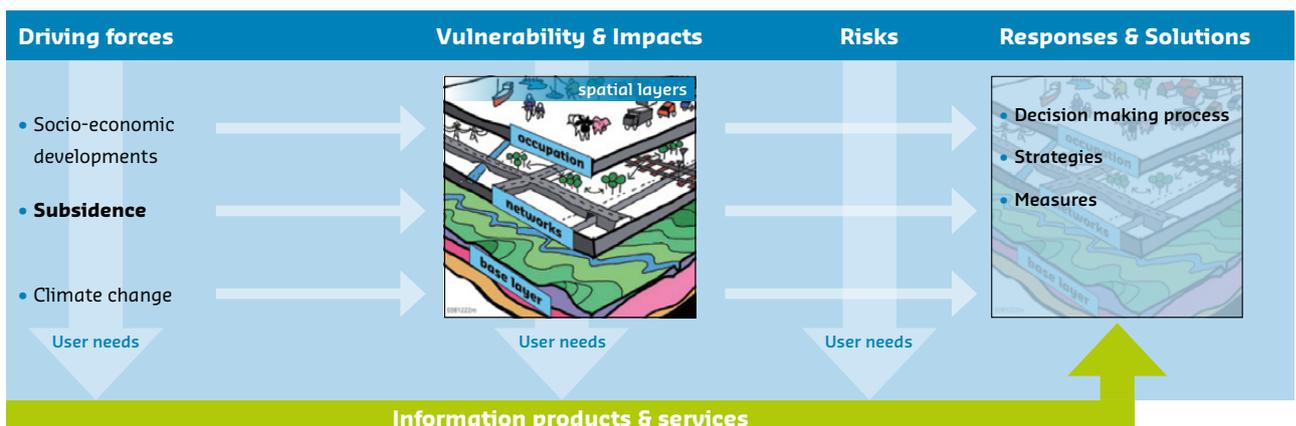
Causes, impacts and adaptive measures

Land subsidence is a problem, with immense socio-economic impacts, especially in coastal areas and urbanized deltas. Subsidence results in increased flood vulnerability, changing groundwater levels, salt water intrusion and reduced crop yields. Moreover, damage to roads, subsurface infrastructure and buildings are some of the results of subsidence in urban areas. The total damage worldwide is estimated at billions of dollars. Subsidence is an issue that involves many policy fields and therefore requires an integrated approach.

Although the impact of subsidence is receiving more attention, more effort is needed to raise awareness, to gain insight into the driving forces and to identify possible coping strategies and measures. Deltares offers an integrated, cost-efficient approach to deal with the issues of subsidence in order to enhance the resilience and sustainable development of deltas, coastal areas and river basins. We develop new concepts for subsidence reduction as well as adaptive strategies and solutions for subsidence reversal, based on an assessment framework addressing several stages in the process of subsidence.

What is subsidence?

Subsidence is the decrease in height of ground level caused by natural phenomena (tectonics, erosion), or by human activity such as loading by heavy structures, change of water level, groundwater extraction and mineral mining (gas, oil, salt). Especially human activity, caused by socio-economic developments (urbanization, need for resources), are currently a major cause of (severe) subsidence.



Some major impacts of subsidence are:

- Increased flood risk;
- Damage to buildings, foundations, infrastructure (roads, dikes) and subsurface structures (drainage, gas pipes etc.);
- Disruption of the water management and related effects (increased salt water intrusion, reduced crop yields, droughts etc.);
- Increased CO₂ emissions due to accelerated oxidation of peat areas;
- Nutrient leaching;
- Reduction in biodiversity and ecological value.

These impacts are exacerbated on the long term, by climate change impacts, such as sea level rise, increased storm surge and change in precipitation.

Deltares approach on subsidence

Deltares can implement a multi-sectoral and multi stakeholder approach, taking into account knowledge of technical, socio-economic and governance aspects on short and long term.

We offer support on the following topics:

- Measuring and monitoring of the current subsidence situation;
- Analyzing and identifying subsidence trends and causes over time (natural and human-induced);
- Predictions of subsidence and risk analysis for different socio-economic and climate change scenarios (modeling);
- Adjustments in spatial planning in urban and rural areas taking subsidence into account;
- Building knowledge and experience of local and regional subsidence, through researching the interaction between soil and structures such as foundations, infrastructure, flood protection;

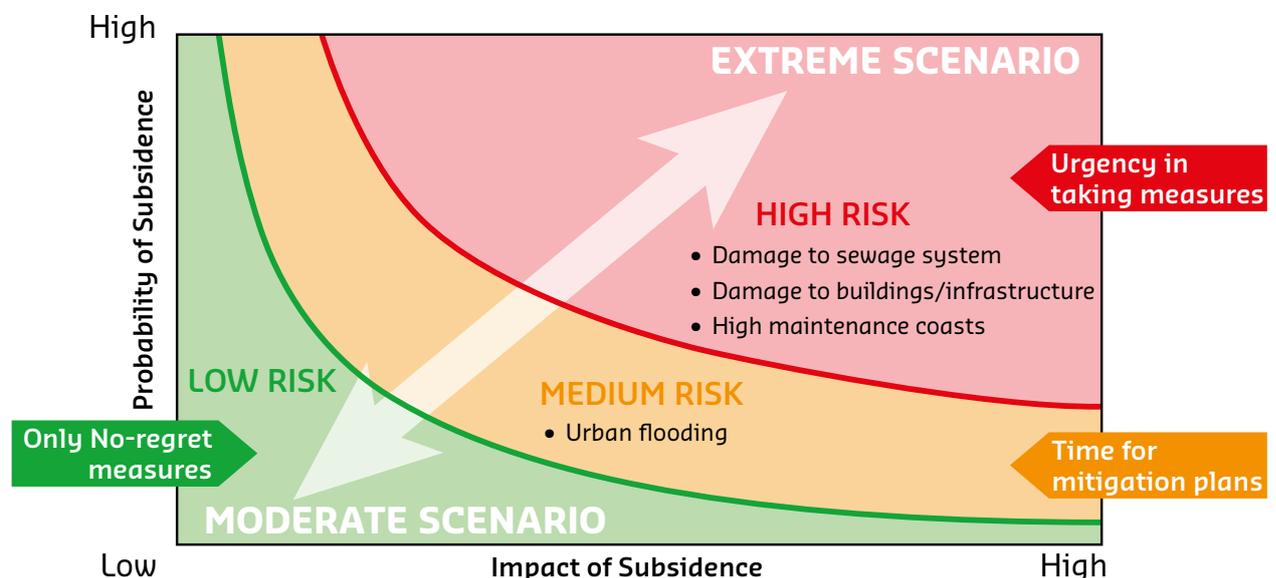
- Alternative solutions for water supply and ground water extraction in order to minimize subsidence;
- Developing and applying adaptive measures to deal with subsidence;
- Subsidence reversal measures;
- Monitoring the effectiveness and impact of (adaptive) measures.

The Deltares approach is based on taking characteristics of the subsurface and groundwater into account at an early stage in spatial planning processes. This results in reduced construction risks, faster building times, cost saving and improvement of the construction environment. In addition, the long term maintenance costs may be considerably lower.

For each case, a risk analysis should provide insight in the impact level (risk level) of subsidence, including possible interactions of scenarios and other drivers, in order to prioritize actions.

The close links that Deltares has with the business community (contractors, engineering firms), increase the feasibility of innovative solutions such as Building with Nature and other eco-engineering solutions as well as the more traditional solutions.

Apart from the technical side of subsidence, the socio-economic and governance aspects are also considered. This involves among others cost-benefit analysis, assessment of institutional structures and related working processes, and capacity building. Regarding the process Deltares ensures stakeholder participation in all phases of the project. Optimal solutions are only achievable through an integral multidisciplinary approach, taking into account the needs and requirements of all those involved.



Example of a risk diagram; if the risk level for a theme is considered high, the urgency to take measures is also high

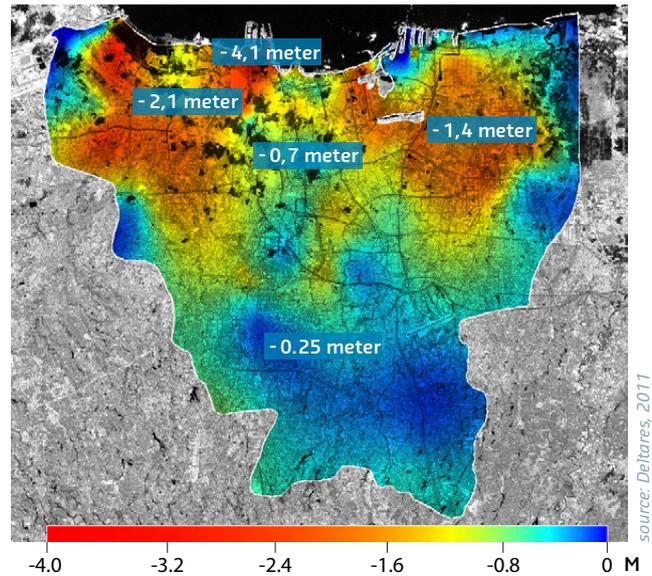
Subsidence projects

The subsidence-free city of Almere (The Netherlands).
 To raise a sense of urgency regarding unnecessary (social) costs of landsubside in Almere, a public private partnership, which includes Deltares, will deliver a rough estimation on the social costs of the expected subsidence for the municipality of Almere and the residents of three of its suburbs. In addition, the specific causes of these costs are identified. This leads to a better understanding of the necessity for including a life cycle analysis in the construction of new urban areas. Almere is still developing new suburbs and the acquired knowledge is directly applicable in new construction projects. The ultimate goal is to demonstrate that an objective quantification of costs is required to make a sound decision on site preparation and construction. Almere is now in a position to adapt the design of new housing developments in accordance with the potential subsidence of the subsurface.

Severe subsidence in Jakarta

Jakarta is located in a low area near the sea in the delta of thirteen rivers and is therefore vulnerable to flooding. Moreover, there is very serious land subsidence, caused mainly by deep groundwater extraction. The current average land subsidence rate is 7.5-10 cm/year along the coastline. The costs for subsidence damage and the consequential damage in Jakarta, will continue to rise in the future, due to population growth in the delta and the increasing need for drinking water.

Using an integrated approach in groundwater management and flood risk management, Deltares can examine the interaction between groundwater management, land subsidence and flood risks. For the Jakarta case, Deltares prepared a special simulation program to estimate the effect of the control of deep groundwater



Land subsidence in Jakarta in period 1974-2010

extraction on land subsidence. It was concluded that by controlling groundwater extraction, subsidence can be greatly reduced. Based on measurements, modeling and simulation, it is possible to identify the most appropriate adaptive measures.

Mekong Delta Plan for integral solutions

Projections for climate change in the Mekong Delta until 2030 reveal among others, increasing flood risk, seasonal water shortages, increasing salt water intrusion and ecological threats. For the same period, an increase is expected in economic development and population, expansion of urban centres and associated development of infrastructure (roads, major bridges, industrial estates, water supply and treatment facilities). This makes the Mekong Delta one of the most vulnerable coastal areas in the world and subsidence is considered as an important factor for increasing problems.



Land subsidence by ground water subtraction

The Vietnamese Government, with assistance from Deltares, is trying to come up with a long-term, multi-sectoral and affordable approach to address these challenges: the Mekong Delta Plan. When developing adaptation and mitigation strategies, underlying challenges concern, among others, understanding of sectoral and cross-cutting issues such as subsidence. This may include the regional socio-economic and demographic dynamics (including Ho Chi Minh City), as well as the resilience of local communities.

The Deltares experts will work together with Vietnamese delta-experts to come up with integral solutions for the Mekong Delta, addressing subsidence and putting this issue into a broad perspective.

Peatlands in South-East Asia

There are 27 million hectares of peatland in South-East Asia. This is almost 10% of its land area. Uniquely in the world, these peatlands are covered with tropical rainforest in their natural state. However, rapid peatland decomposition is presently occurring in Southeast Asia. Peatlands are being deforested and drained for development of plantations, agriculture and logging. As peat consists of 90% water, subsidence is severe in those areas. This results in future loss of agricultural production due to increased flooding. Moreover reduced water levels are causing globally significant CO₂ emissions by oxidation of peat.

In Indonesia Deltares is involved in among others research on the processes of peat decomposition and subsidence, development of (spatial) planning tools and training programmes.

Subsidence in coastal lowlands in Europe

The EU FP7 project SubCoast aims to support decision making on policy, adaptation strategies and operational measures dealing with subsidence, by developing a portfolio with information products and tools based on various information sources. State-of-the-art radar satellite technology for large scale subsidence mapping is applied, building upon GMES services.

In the SubCoast pilot areas (The Netherlands, Baltic and Italy) an Assessment Framework is introduced by Deltares as a guideline to inventory stakeholder information needs and to develop appropriate information products that can support decision-



Flooding in the Mekong Delta

making. This involves assessment of driving forces (interrelated with subsidence), impacts, vulnerability of land use functions, infrastructure and associated risks, and identification of appropriate measures. The entire chain of governance is addressed: from national policy makers to local authorities and experts. Also cost benefit analyses are taken into account. This integrated approach elaborates the technical, socio-economic and governance aspects of subsidence.

Deltares clients and network

Our national and international clients include government authorities, policy makers and authorities responsible for operational and strategic (water) management. In the private sector, our clients are consultants, contractors and insurance companies. National development and agencies, the European Commission, the World Bank and the Asian Development Bank are regular clients.

Deltares is an active participant in various networks and joint research programmes in The Netherlands and abroad.

Deltares is a founding member of the Delta Alliance, an initiative to promote inter-delta cooperation among experts, water managers and other practitioners. The Delta Alliance aims to share knowledge and practical experiences, raise awareness and develop tools for sustainable development of low-lying areas in a changing world and a changing climate.

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