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Water supply on the island Terschelling

by Arjen Kok

The island of Terschelling is situated in the Wadden Sea in the northern part of The Netherlands. It measures 30 km by 3 km. An extensive belt of coastal dunes extends along the north and west sides of the island, which is vegetated mainly by dune shrubs and pine trees. South of the dunes is an agricultural area (indicated as "polder" area) where water levels are artificially maintained.

These water levels are lower than the groundwater table in the dunes so there is a steady flow (ground- and surface water) towards the polder area and the North Sea. The island is a popular holiday destination and the demand for drinking water is strongly related to the number of tourists on the island, which peaks during summer time. The annual water consumption averages 550,000 m^3/year. Approximately 200,000 m^3/year is produced annually by the well field that **(cont'd./. . . 2)**

Editorial

The water challenges forced by climate change must be solved by a broad professional cooperation both national and transnational. An early adaptation strategy should include all of the affected sectors and authorities and their planned activities, like new buildings, roads, etc. This will give communities a strong base for meeting the challenges caused by climate change.

Directive 2007/60/EC on the assessment and management of flood risks entered into force on the 26th of November 2007. This Directive requires Member States to assess water courses and coast lines that are at risk of flooding and the associated adverse consequences for human health, the environment, cultural heritage and economic activity in those areas and to take adequate and coordinated measures to reduce the risks.

The Directive requires that Member States carry out a preliminary assessment to identify areas at risk of flooding by 2011. Member States must develop flood risk maps by 2013 and establish flood risk management plans by 2015.

The challenges and requirements for mapping and flood management set out in the directive necessitates advances in data collection, mapping and surface and groundwater flood warning systems. This involves integrated surface and ground water models that incorporate the geological and hydrological knowledge that is based on data collected from a large range of methods. The CLIWAT project will develop such models in most of the pilot areas.

It is important that any subsequent adaptation strategy is based on solid scientific knowledge. The increased scientific knowledge will lower the degree of uncertainty and give a more precise interpretation of the hydrological effects of climate change. Greater certainty means fewer resources are needed to meet the challenges.

In 2007, the Dutch government appointed a group of nine scientists to form the *Delta Committee*. The committee was given the mandate to propose recommendations on how to protect the Dutch coast and low-lying land against the consequences of climate change. The committee produced a report in 2008 that listed 12 recommendations. These included raising the flood protection levels of all diked areas by a factor of 10, continuing beach nourishment, security of water extraction and raising the IJsselmeer lake by a maximum of 1.5 meters to secure drainage to the Wadden Sea. Certainly factors that require long term investments. This is an excellent example of recommendations and requirements for adaptation to climate change made at a national level. Similar work should be carried out in other EU Member States.

Flood risk management is an urgent factor, and must be taken into account in future planning. Local, regional and national authorities must deal with the risk of flooding in the future. The statement issued by the UK Environmental Agency July 2009, warning that: "over five million people in England and Wales live in properties that are at risk of flooding from rivers or the sea" underlines the importance and urgency of the matter.

Climate change will affect us all and water is a common challenge. The CLIWAT group will develop groundwater prediction models that learn from the future and make the North Sea region a better and safer place to live in.

We hope you will find the newsletter interesting, and invite you to leave comments and ask questions on our web site www.cliwat.org, where you are also able to subscribe to the newsletter.

Kind regards

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The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

About CLIWAT: Adaptive and sustainable water management and protection of society and nature in an extreme climate

The project will focus on the effects of climate change on groundwater systems. CLIWAT aims to identify the challenges caused by the higher water levels, and to develop climate scenarios focusing on surface water and water supply as well as the impacts on buildings. The quality changes of the groundwater resource caused by salinisation, outwash from point sources and new demands for irrigation are some of the issues which will be investigated. This will enable the North Sea Region to react more efficiently to the consequences of climate change. The project will build on and improve existing geophysical and geochemical methods; these will be tested in the partner regions in order to be able to develop ground water models and furthermore recommendations for the North Sea Region on how to deal with the consequences of increased groundwater levels.

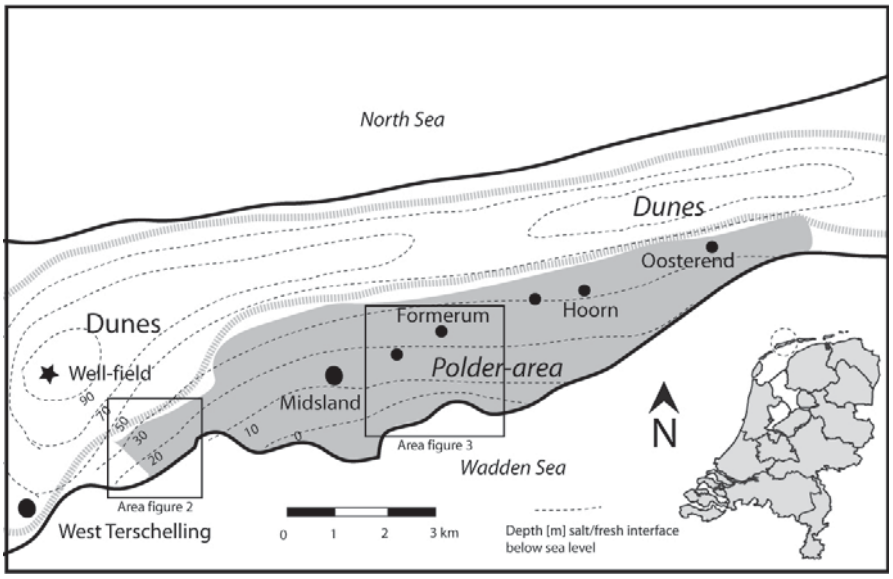

***Figure 1**: Groundwater levels on the island of Terschelling*

(Continued from p.1) withdraws groundwater from the fresh water lens in the western part of the dune area (see Figure 1). Approximately, 350,000 m^3/year is delivered to the island by a pipeline from the main shore. In 2006 Vitens (water supply company) has started a pilot study to investigate if a self supporting and sustainable water supply on the island is possible. One of the options to be considered is to increase the abstraction of fresh groundwater in the dunes or polder area. A groundwater model is being developed to assess the feasibility of various design alternatives, the risk of salinisation and the potential ecological consequences for dune slacks. In order to calibrate the groundwater model sufficient data are required regarding the distribution of fresh and saline groundwater on the island as well as the presence of confining strata.

In 2007 an intensive field campaign was launched to collect the required data. Geophysical methods (based on resistivity) combined with cone penetration tests (CPT's) were used to map both the groundwater salinity and lithology. In the polder area the sediments in the upper 5 meters of the subsurface consist of tidal flat and salt marsh deposits composed of clay, silt and sand of Holocene age. These deposits partly extend below the present dune belt. The sediments below the Holocene strata predominantly consist of Pleistocene coarse sands of fluvial origin. Intercalations of silt, peat, loam and clay layers can occur at various depths in a very irregular fashion. Standard DC geo-electrical investigations during the 1960's have shown that a fresh water lens with a maximum thickness of 100 meters has developed in the dune area Hoogervoorst (1970). Also the location of a fresh and saltwater interface in the "polder area" was interpreted. The fresh water lens is recharged by rainwater infiltrating in the dune area.

Methodology

According to the measurements, carried out in the 1960's, part of the fresh groundwater flows towards and underneath the polder area. Prior to the field campaign the existing geo-electrical measurements by Hoogervoorst were critically re-evaluated to obtain a general overview of the resistivity distribution of the subsurface below the island. The fresh and salt water interface seemed to be more complicated than the interpretation's in the sixties. Based on this information, a number of 400 m transects were selected for continuous two-dimensional vertical electrical soundings. To minimise equivalence problems during the interpretation of the CVES (Continuous Vertical Electrical Sounding) to overcome similarities in resistivity of different lithologies, 33 cone penetration tests with a conductivity probe were conducted in the polder area and at the beach. With the standard truck mounted 20 ton hydraulic system a maximum depth of 32 meters was reached. These CPT-measurements provided ground-truth measurements of the subsurface resistivity and information about the lithology.

Results of the fieldwork

With the 33 CPT's and the 10 CVES profiles it was established that rapid changes of water quality and lithology occur in the polder area. The depth of the salt / fresh groundwater interface in this area varies between zero and 50 m. The CPT measurements provided valuable and detailed information regarding lithology and conductivity, and facilitated the interpretation of the CVES profiles. The general pattern is that the depth of the interface between fresh and salt groundwater is deepest below the coastal dune, and decreases towards south in the polder area (figure 2). The survey revealed unexpected new insights in the groundwater system. At particular

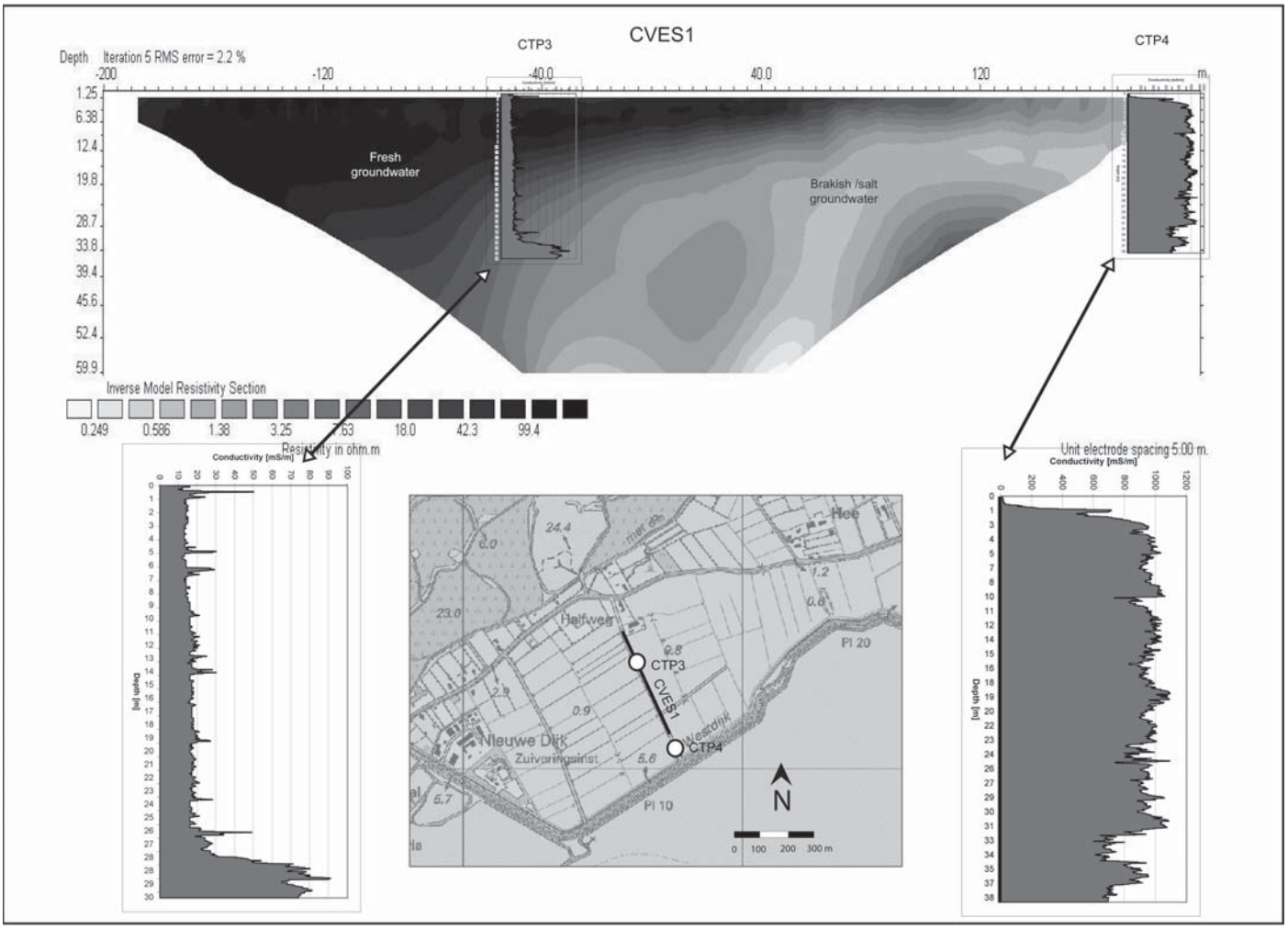

***Figure 2**: North-South transect in the polder area showing the resistivity distribution as measured with the CVES and the conductivity with depth at two locations along the CVES transect as measured with a conductivity probe*

locations in the polder area, for example south of the village of Landerum, the interface is much shallower than expected. This phenomenon is related to the presence of tidal channels up to 500 years ago, before the present polder was developed.

The pattern of the depth of the interface in these areas is much more complicated then it was previously calculated with MODFLOW and the SWI package. The newly obtained information about the lithology, and water quality was used to improve the calibration of the groundwater model. This resulted in a better fit with reality, and therefore should also result in a more realistic prediction of the effects of possible activities. The CVES and CPT measurements that were carried out on the beach at low tide revealed the occurrence of fresh groundwater below a 15 m thick layer of saline groundwater up to 60 meters below sea level at the low water line. Similar results were found in the vicinity of De Panne and Wassenaar, along the coast of Belgium and the western part of the Netherlands. Further investigations will be carried out to establish if this fresh water lens is part of the present hydrological system or a relic of the former fresh water lens that became submerged by the sea as the island migrated south in this highly active sedimentary environment.

***Figure 3**: CPT measurements on the beach (© Wiertsema & Partners)*

The contribution of the CLIWAT project

CVES and CPT measurements generate useful point and line information, about lithology and the depth of the fresh water / salt water interface, but not a 3D detailed overview. With the CLIWAT survey it is possible to develop such detailed salinity distribution maps. In September 2009 the Danish 'Sky TEM', of the university of Århus will be used to map the fresh water lens under and outside the island. With the CLIWAT project it is (hopefully) possible to measure how the fresh water lens is developed north of the coastline. Furthermore, it is possible to look trough the layer of sea water, to discover the fresh water. In addition, the Free University of Amsterdam developed a CVES cable system to measure on the sea floor. A new fieldwork campaign will give plenty of information to compare with the Sky TEM measurements. Both surveys will give us answers to yet unresolved aspects of the salinity distribution under and outside the island.

Conclusion

For the future of the water supply on the island Terschelling the InterReg project CLIWAT is essential. That is why the water supply company Vitens is a partner in this project and Terschelling is a pilot area. Once we know more about the salinity distribution in detail, it possible to say more about the effects of sea level rise and climate change for the interface of salt and fresh groundwater. Movements of this interface upwards can have serious consequences for the water supply on the island in the future. In the InterReg project 'Cradle to Cradle islands' (C2C) the aim is to make the islands self-supporting for there energy and water use. There is a very clear link between these InterReg projects. Information of the salinity distribution as a result of CLIWAT will be the input for a sustainable water supply planning in the C2C project.

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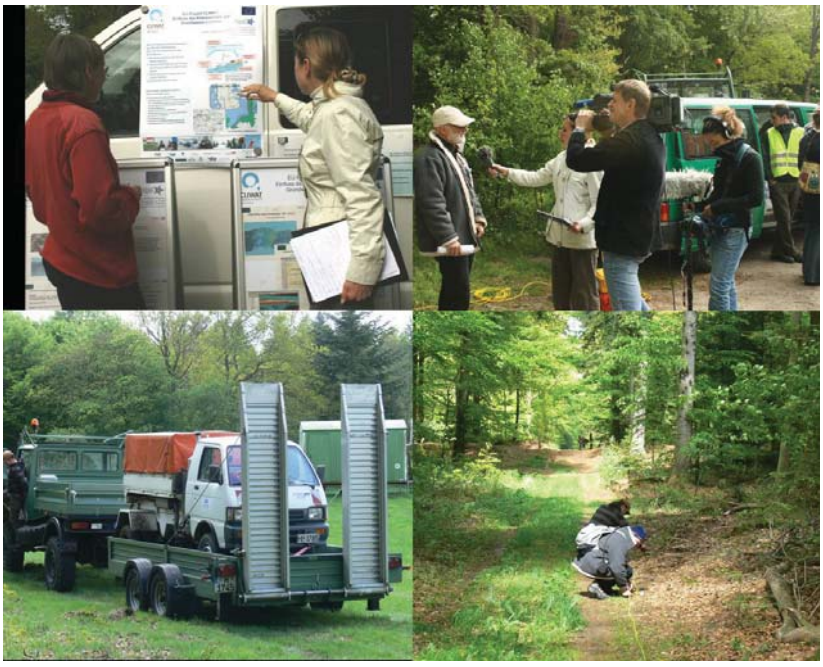
CLIWAT stakeholders at the first seismic survey campaign

by Wolfgang Scheer, Helga Wiederhold and Reinhard Kirsch

A sunny Friday morning on a parking place in the forest near the waterworks of Karlum. Normally a lonely place visited mostly by hikers, now it is crowded with journalists, geologists and the seismic team of the LIAG institute.



Impressions from stakeholder meeting and seismic field survey (clockwise): discussing CLIWAT aims with a journalist, interview of CLIWAT partner, "planting" the geophones, the vibrator vehicle arrives in the field (© Reinhard Kirsch, Helga Wiederhold)

The first seismic measurements for CLIWAT in the Danish-German project area were used for a project presentation. Wolfgang Scheer (LLUR) and Helga Wiederhold (LIAG) gave an introduction to CLIWAT and the special conditions in this project area, followed by a field demonstration of seismic techniques by the LIAG crew. Visitors came from the nearby waterworks, geological companies working in this area and water administrations from both sides of the Danish/German border.

The aim of the seismic survey is the delineation of the geological structure relevant for the groundwater systems. In principle the method is comparable to an echo sounder or sonar used on ships to map the sea floor. The small vibrator vehicle of LIAG transmits sound waves or elastic waves into the ground, reflections from layer boundaries where material properties change are recorded on the surface by the geophones. The wave field emitted by one "shot" is recorded by 264 geophones for a time series of twelve seconds sampled every millisecond. The seismic survey deals with a huge amount of data. In the last two weeks five profiles were recorded with in total 815 so-called "shotpoints" resulting in 7.8 'line' kilometres.

The seismic section that gives the structural picture is only available after some special and complex data processing. Together with other geo-

physical data (e.g. from airborne electromagnetic survey) these will be integrated into the geological model.

Reports on this meeting were shown on TV (NDR Schleswig-Holstein Magazin, 16/05/2009) and in the newspapers (Husumer Nachrichten, 16/5/2009; Kieler Nachrichten, 10/06/2009). The next stakeholder meeting with colleagues from Danish and German waterworks in this area is planned for fall 2009.

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Intense field campaign on the island of Borkum

by Paul Königer, Hans Sulzbacher and Helga Wiederhold

More than 15 technicians and scientists were working on the island of Borkum during an intense hydro-geological field campaign within the CLIWAT program. The aim of the campaign is to gain better knowledge of the geological and hydro-geological conditions with respect to a sustainable water supply for the future.

Several field campaigns were conducted on the island of Borkum so far. However, in September 2009 the most intense campaign was carried out involving more than 15 technicians and scientists from Denmark and Germany. In international and interdisciplinary co-operation scientists and technicians from the Region Midtjylland (MIDT), Geological Survey of Denmark and Greenland (GEUS), Danmarks Tekniske Universitet (DTU) and Leibniz Institute for Applied Geophysics (LIAG) established new groundwater observation sites for pumping tests, installed novel in situ instruments and performed hydro-geological experiments on the island.

Borehole drilling and data logging in the Ostland catchment of the island of Borkum (© Paul Könger)

Near surface measurements with ground penetrating radar were conducted in the first week along several transects. Shallow borehole drillings (up to 7 meter depth) were established for pumping tests and flow logs on seven remote locations. Investigations using the GEOPROBE ® direct push device for underground investigations and sample collections were conducted in the second and third week.

GEOPROBE ® subsurface tests for a characterisation of underground structure and water sample collection conducted by colleagues from DTU and GEUS (© Paul Könger)

The municipality of Borkum (Stadtwerke Borkum) and a German drilling contractor drilled two new boreholes down to depths of 70 meters at Waterdelle and Ostland, which are the major water supply areas on Borkum. The new drillings allow detailed studies of underground substrate, aquifer structures and geology through data logging in the open boreholes. Conductivity chains with sensors located in a distance of every 25 cm were installed in depths of 40 to 60 meters. The sensors allow a continuous observation of conductivity changes with depth, and therefore a direct reflection of variations in the salt – fresh water interface. Finally those new boreholes were equipped with multi-level groundwater observation wells. In several groundwater supply wells data log-

gings and camera measurements were conducted. All activities were combined with intense groundwater sampling to allow water quality and isotope-hydrological characterisation as well as groundwater age dating and recharge estimation. The data collected during the field work will allow a detailed characterisation of substrate and underground parameters which are needed for geological and hydro-geological modelling.

All members of the various groups appreciated the opportunity for permanent discussions and scientific exchange about methods or equipment as well as future plans and requirements. The discussions often lasted until late in the night were probably one of the most exiting points within field campaign. The intense work on the island was not possible without the acceptance of local residents and their occasional active support. The involved technicians and scientists have left with lots of data in their backpack that have to be evaluated during the forthcoming months.

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Exchanging ideas, knowledge and equipment - a transnational cooperation

by Rolf Johnsen

As part of the CLIWAT project we are trying to exploit partners' know-how and experience. This includes exchanging knowledge and equipment. The meeting in Horsens concerned the planning of upcoming field work at Borkum and at the landfill site near Århus (Eskelund).

Activities at the workshop (©Tom Birch Hansen)

The investigation of groundwater contamination risk from point sources at Eskelund and the intrusion from sea water to groundwater at Borkum are using the same methods: drillings and pump tests. During a preparation meeting in August 2009 a number of technical details where discussed: how much to pump, how deep the drillings should be, how far the wells should be to represent the explored aquifer etc.. Additionally, more practical issues were discussed, and the drilling equipment was demonstrated, which raised other issues such as what to do with the upconed soil.

A drilling team led by Henrik Rud Larsen from *Central Denmark Region* will travel to Borkum to carry out seven drillings in September 2009. The drillings will enhance the geological data, and make it possible to take water samples from a relatively unknown area. The drilling team will stay at the island for about four days. Other CLIWAT investigations from GEUS and LIAG will also be carried out in the same week.

A crew from LIAG led by Hans Sulzbacher will visit Århus in October 2009, and perform a long-term pump test. The test will enhance our knowledge about the links between contamination, the river, aquifers and the nearby waterworks. Furthermore, aquifer parameters, such as hydraulic conductivity and leakage will be investigated.

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The 2nd CLIWAT partner meeting

by Rolf Johnsen

During two sunny days in April the CLIWAT group gathered on the island of Terschelling for the second partner meeting. The meeting was hosted by the Dutch water provider Vitens in the hotel *Oepkes and Westerkerk* .

It became quite clear during the first day, that a much field work was initiated in the seven pilot areas. Details from each of the pilot areas where delivered with a lot of emphasis on the preliminary results. Furthermore, board organisation and stakeholder commitment was initiated. The first meetings were implemented in the participating countries. There is

generally a great interest in the project in Belgium, Denmark, Germany and the Netherlands.

Participants at the partner meeting (© Holger Lyngklip Strøm)

Stakeholders from a wide range of sectors are now involved in the CLIWAT project. A bike trip around the island was arranged including visits to local drilling sites that supply domestic water. The island's water lock that controls the tidal water and drainage was another destination. The domestic water supply on Terschelling depends on water extracted from the island and water imported from the main land. Vitens and the local municipal authorities are planning to increase the percentage of water extracted from the island in the future.

On the last day the CLIWAT group continued to develop its vision and mission and agreed on a common mission/proclamation for the project: Climate change affects us all! To foresee upcoming changes in water systems and start a proactive adaptation process for the protection of society and nature.

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Stakeholder involvement in national boards initiated

by Sophie Rotter

The active involvement of stakeholders within the CLIWAT project plays a central role and is gaining momentum. In the first half of 2009 meetings with stakeholders were organised in all partner countries.

In March and May the **national boards** were established in Denmark, Belgium and The Netherlands. In January and May the German project partner held several meetings with stakeholders in various locations including, for example, the islands of Borkum and Föhr as well as in Karlum close to the German-Danish boarder. Due to various reasons a German-Danish cross-boarder meeting planned for September 2009 had be postponed to January 2010.

Although the structure of the national boards is based on a generic description of participatory processes, the individual board meetings as implemented by the project partners in the four countries are adapted to the national requirements. As a result, the national boards vary in size and composition of participants. Nevertheless, a number of activities have been implemented by each of the national boards in the first meeting:

- informing the participants about the CLIWAT project and scheduled activities in the pilot areas;
- questioning the stakeholders about their expectations of the CLIWAT project and its results.

Within all boards the participants raised open questions related to ecological and agricultural issues, as well as country-specific issues such as salt water intrusion, water supply and polluted sites.

The second round of national board meetings is already scheduled for the partners in Denmark and Belgium in September and October of this year. In addition to presenting actual project results, during these meetings, stakeholder requirements will be further defined and discussed in more depth. Moreover, representatives for the upcoming first transnational board meeting on the 27^{th} of November will be elected. Stakeholders from each of the case study countries will be represented at this meeting. The objective of the transnational board meeting is to strengthen the international co-operation, exchange experiences, and discuss cross-cutting issues that are relevant for all four partner countries.

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Terschelling at dusk (© Holger Lyngklip Strøm)

Schedule of events

Events				
Date	**Event**	**Content**	**Location**	**Link**
17/9/2009	Danish NBM	Second National Board Meeting of the Danish partner	Horsens	http://cliwat.eu
Sept/2009	SkyTEM	Århus Sky TEM survey	Northern Frieslland and Terschelling	http://cliwat.eu
02/10/2009	Belgian NBM	Second National Board Meeting of the Belgian partner	Ghent	http://cliwat.eu
27/10-29/10/2009	Symposium	International Symposium "Strategies for Adapting to Climate Change in the Regions of Europe"	Düsseldorf	http://www.regional-climate.eu
Oct – Nov/2009	Field measurements	Field measurements	Northern Frieslland and Terschelling	http://cliwat.eu
10/11-12/11 2009	ACQUA ALTA Conference	Conference and exhibition on consequences of climate change and flood protection	Hamburg	http://www.hamburg-messe.de/
25/11-27/11/2009	CLIWAT partner meeting	CLIWAT partner meeting and transnational board meeting	Copenhagen	http://cliwat.eu
08/12-17/12/2009	COP15	UN Climate Change Conference	Copenhagen	http://en.cop15.dk

The above dates and locations may change. The editors are neither responsible nor liable for any inconvenience resulting from such changes.

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