POSITION PAPER

on the potential and scope of collaboration between IBM – Big Green Innovations and the climate and water communities

Wageningen, 2 November 2007

Authors:
Ir. Anne van Loon, Dr.ir. Henny van Lanen, and Prof.dr. Pier Vellinga

With contributions from:
Steering committee: see Annex 2

WAGENINGEN UNIVERSITY WAGENINGEN UR

IBM

ALTERRA WAGENINGEN UR

Executive summary:

A major concern for companies and governments is the robustness of their activities and investments in view of a changing climate. The water sector is in need of technological innovations to be able to cope with the effects of changing climate on the water system. IBM is searching for a way to utilize the computational power of its supercomputers and its expertise and capabilities on sensor networking, date streaming and visualization, to satisfy the needs of the water sector. Commissioned by IBM, the Centre for Water and Climate of Wageningen University and Research Centre (WUR) has carried out a study in cooperation with European research partners that resulted in this position paper. The aim of the paper is to present an overview of the opportunities for improving and utilizing monitoring systems and sensors, weather/climate prediction systems, and their coupling to hydrologic models, hydrological forecasting tools and use in water management.

In Europe water-related issues are dealt with in international collaboration, both institutionally and scientifically, with countries like Germany, United Kingdom, Denmark, Norway, France, the Netherlands, etc. In this paper we focus on the water sector in the Netherlands within this European context. Water management in the Netherlands is a direct responsibility of the Ministry of Public Works and Water, and 26 water boards. Water users, although sometimes only indirectly dependent on water, increase profits or reduce economic losses by increasing the efficiency of their water-related activities. Better monitoring and forecasting systems that balance between water excess and shortage, are an important tool to achieve that. Business opportunities in the water sector are large, but major investments can be expected only when a certain system has proven its value. Therefore, successful pilot projects are extremely important to convince water managers and water users to invest in innovative systems and tools. The water sector in the Netherlands is not unique in the sense that comparable situations, regarding both the physical and the administrative system, are present in delta areas around the world.

An inventory of research projects of WUR and partner institutes in the field of climate and water revealed a range of interesting options for collaboration, i.e. with the institutes KNMI (Royal Netherlands Meteorological Institute) and Deltares, and with the programs/projects Climate Changes Spatial Planning, Knowledge for Climate (KvK), EC-Earth, and Flood Control 2015. Based on interviews with water users, water managers and partner institutes, urgent problems are identified that are considered critical to solve and that require technological innovation. These are large-scale, complex issues that arise in a multi-client environment. The most promising areas for collaboration between IBM and the climate and water communities are the following:

1. *Improving water management in urban and peri-urban areas using tailor-made prediction and decision support information services,* with interested clients like drinking water companies, Water Boards, the Ministry of Spatial Planning, and the urban development sector, and with a consortium of KIWA (research organization of drinking water companies), STOWA (research organization of water boards), KNMI, ECMWF, IBM, and WUR;
2. *A comprehensive observation and modeling system for prediction and management of floods in delta areas like the Netherlands*, with interested clients like the Ministry of Public Works and Water and other public entities, research organizations, and insurance companies, and with a consortium of Deltares, KNMI, ECMWF, IBM, and WUR.

To solve these large scale critical problems, scientific research, technological development, practical experience, and innovative schemes of business development go hand-in-hand. Integrated systems should be developed by IBM and partner institutes to serve the public and commercial water sector. These integrated systems should include sensor networks, climate change prediction, hydrological forecasting, modeling tools, decision support systems, and visualization tools to support operational water management and investment decisions.

In parallel to these large-scale promising areas, a number of urgent specific technical needs have been identified based on the requirements of a specific client (group). These are:

- Waternet (a combined water board, drinking water utility and sewage system organization in Amsterdam): *Observation and modeling of the entire water cycle to improve efficiency in regional water management in a densely-populated area*;
- Electricity generating companies (i.e. Essent and Electrabel): *Monitoring and prediction of river discharge and temperature for use as cooling water*, or *Estuary Observatory Network in the Waddensea*;
- River transport sector: *Developing a monitoring tool for water depth to increase river navigability*;
- Nature and agriculture: *Developing a tool for drought multi-month forecasting and the effects on nature and crop yield through the water system*.

The possible pilot projects focus on the development of a transferable system. This would greatly enhance its adoption by other clients in the same sector, and thus its commercial attractiveness. This applies both for clients in the Netherlands as well as abroad.

The two most promising large scale areas, and four smaller scale technical needs, identified above, are more elaborately described in this position paper. During the following phase of the exploration of IBMs business opportunities in the climate and water sector, discussions should point out on which pilot projects we will focus and which consortia we will form. After choosing a focus, we should elaborate the proposal for pilot project(s) together with the specific client (group) and research partners involved, and make their investment intentions more concrete. One or more early-wins are within reach, with contribution of the ongoing Climate Changes Spatial Planning, and Knowledge for Climate programs. The clients in the water sector are very eager to start working on these innovative pilot projects to be prepared for the effects of changing climate on the water system.

1. Introduction

1.1 Background

Water-related disasters, like droughts and floods, have a major impact on human well-being. They affect the environment (e.g. the quality of water, food and nature) and the economy (e.g. through health, urban activities, food production, transport, energy provision and recreation) we depend on. These impacts are serious as they cause loss of life and property, and especially in developing countries, aggravation of poverty and mass migration. Impacts are likely to increase with time as more people settle in vulnerable areas and societies' demands on water and environmental services increase. For instance, over the last 20 years, four significant large scale droughts have occurred in Europe that have covered more than 800.000 km^2 (37% of the area) and that had an effect on more than 100 million people (20%). About 26.000 people died during the 2003 drought in EU and the damage has been estimated at 13.5 billion US$. Worldwide, 31 million people were affected by drought in 2006. A similar number also holds for floods in 2006, although loss of life due to drought is generally larger. On top of that, climate change comes with an increase in extreme weather events as reported by the Intergovernmental Panel on Climate Change (IPCC, 2007).

A major concern for companies and governments is the robustness of their activities and investments in view of a changing climate. Two major developments have an influence on the quality of the estimates of weather-related risks and opportunities. One is the fact that statistical analysis of historic data does not hold anymore as the climate is changing. Historic data as a reference for the operational management of major water schemes and for the insurance of investments vulnerable to specific weather events is not the most reliable basis anymore. In weather-related risk assessment the trend of climate change will have to be taken into account.

The second development is the improvement of the reliability of weather and climate prediction tools/ models and hydrological forecasting tools. Driven by concern about global climate change, the quality and reliability of climate models has improved considerably over the last few decades. Simultaneously, the quality of medium and long range weather forecasting has improved. The existing weather forecasting models are increasingly capable of covering a longer time period and the reliability of such predictions in statistical terms has improved considerably. However, the applicability of the weather forecast data to hydrological analyses and models, and the use of climate predictions and weather forecasts in water management are significantly lagging behind. This also applies to drought forecasting, including the propagation of meteorological signal in groundwater and surface water. There is an enormous challenge for the meteorological and hydrological community to bridge the gap. Climate researchers should provide relevant information to hydrologists and water managers, and water managers should use more climate and weather information in their analyses and decision making.

1.2 The research questions of IBM

The IBM Big Green Innovations Programme in general aims at a better use of computer technology (ICT) in managing our natural resources. According to IBM, the business community should take the lead in that and companies are already searching for methods to use ICT in dealing with environmental issues concerning their daily practice. In particular, sustainable water use is one of the core interests. The private sector can take the lead in designing new processes and practices for sustainable water use, to address the problem of increasing scarcity in reliable fresh water resources in many parts of the world. As the business community needs tools to incorporate these water related issues in their management, IBM can play an important role in providing these computational tools. Currently, IBM is looking at how the computational power of its supercomputers and IBMs expertise and capabilities can be utilised within the water management sector.

To be able to fulfil this promise, IBM needs innovative research and new partnerships. The specific knowledge and expertise of IBM on complex sensor networks, data management and processing, computing technologies, and the business community using IBMs products, should be combined with scientific knowledge on the climate and water system. Through joint multidisciplinary research IBM and the water and climate research sector can co-create the future.

IBM acknowledges that the Dutch water sector is leading in the field of water research and innovation. However, there are large challenges that the water researchers have to face: more complexity of the system is revealed, more accurate prediction is needed, climate change poses a serious threat, economic and social vulnerabilities are increasing, etc. Computer technology can have an important added value. To come to a sound collaboration between the water world (in particular Wageningen University and Research Centre) and the computer world (in this case IBM) a position paper is needed that explores the state-of-the-art, the pressing issues and the way forward in this field. Commissioned by IBM, the Centre for Water and Climate of Wageningen University and Research Centre (WUR) has carried out a study that focuses on the questions above.

1.3 Scope and objectives

In this position paper the aim is to present an overview of the opportunities for improving and utilizing monitoring systems and sensors, weather/climate prediction systems, and their coupling to hydrologic models, hydrological forecasting tools and use in water management. In this paper the focus will be on water management and water use in a broad sense.

The position paper describes and analyzes ongoing and planned research activities in the field mentioned above. Particular attention will be given to the planned research and development investments of the European Union, and in particular one of the most active member states in this field, The Netherlands.

A systematic analysis is presented of new products that can be developed on the basis of improved modeling capabilities. Part of the work was to explore the potential of such new products in the public and in the private domain. The ultimate goal of the position paper was to explore the potential and the practical possibilities of developing a partnership between Wageningen University and Research Centre and its research partners in the Netherlands and in Europe, and IBM in the field described above.

1.4 Methodology

The study is executed by Ir. Anne van Loon under the auspices of Prof.dr. Pier Vellinga. An internal steering committee has been established of people from various disciplines at CWK. The members of the steering committee are listed in Annex 2.

We began this research by carrying out a ‘quick scan’ of sources and knowledge partners, in order to gain a general overview of the policy framework, the research programmes in progress, and of the actors in the thematic field. By carrying out a stakeholder analysis, it was possible to identify the most important knowledge partners, research programmes and organizations that could prove of interest for the activities of IBM.

In addition, a total of 34 experts were interviewed (see Annex 2). The experts were selected on the basis of the stakeholder analysis. In preparation for these interviews, a thematic questionnaire was compiled which formed a useful guide. The results of the interviews formed an important basis for this report.

1.5 Outline of this paper

The position paper consists of seven sections and five annexes.
Section 1. Introduction Background, methodology and outline position paper.

Section 2. Institutional framework and governance Inventory of private and public water sector in the Netherlands.
Section 3. Research organizations and programs Overview of national research projects and partnerships, and international programs.
Section 4. Climate and water modeling and observation system State of the art regarding the development of methods and tools for weather/ climate change prediction, hydrological forecasting, and water management.
Section 5. Key technical challenges Inventory of opportunities for IBM and the climate change and water community to cooperate in the development and market introduction of innovative products and services. Identification of two main focal areas.
Section 6. Short range projects Identification of a number of pressing needs and small scale pilot projects that could be developed.
Section 7. Challenges and opportunities for cooperation Wrap-up, main conclusions and follow up.

Abbreviations

Annex 1: Relevant completed, current and upcoming projects of CWK.
Annex 2: Steering group & List of interviewed organizations and people
Annex 3: Summary Kennis voor Klimaat program.
Annex 4: Description ACER project.
Annex 5: Schematic water chain Waternet.

2. Institutional framework and governance

This section gives an overview of the water sector in the Netherlands. Although only the Dutch water sector is analyzed, this information is in general applicable to many other countries in Europe and outside. The water sector is a broad sector comprising two parts, water management and water users.

2.1 Water management

The water management in the Netherlands is the responsibility of a number of institutes:
- Coast and rivers: Rijkswaterstaat/RIZA (Ministry of Public Works and Water)
- Surface water system & unsaturated zone: Water Boards
- Groundwater: Provinces

Rijkswaterstaat manages the river system and coastal protection in the Netherlands. Predictions of water levels and discharges are obtained by modeling the catchment, including meteorological data of KNMI and hydrological observations, collected by Rijkswaterstaat. Simulation models used by Rijkswaterstaat are mostly developed by WL| Delft Hydraulics. Rijkswaterstaat is interested in innovations to come to better predictions and the expertise of IBM and WUR can be a surplus value.

In the Netherlands 26 *water boards* are in place that are responsible of the surface water management of a specific catchment. They control surface water levels in canals and ditches based on the requirements of urban areas, agriculture, nature and other stakeholders. The umbrella organization of the water boards is called Union of Water Boards. Most water boards do not only manage the surface water system, but also include sewage water treatment, and one even deals with drinking water supply (for drinking water companies: see hereafter). This overall water board is called Waternet. Discussions with water boards, among which Hollandse Delta and Waternet, revealed many interesting problems and needs.

The Netherlands has 12 *provinces* that are responsible for the large aquifers (from 2009 onward water boards take over this task). These provinces grant licenses for groundwater subtraction to farmers, industry, drinking water companies, etc. They, however, do not do operational management of groundwater bodies and therefore do not use monitoring systems or prediction tools for the optimal use of the groundwater resource. The national groundwater monitoring system is managed by the institute TNO-NITG (which will be part of Deltares).

2.2 Water use

The group water users is a very diverse group consisting of direct and indirect water users. The indirect water users, like tourism, are not evaluated in this report. For the direct water users we focused on the following sectors:
- Drinking water
- Transport and infrastructure
- Electricity producing companies
- Construction companies and project developers
- Nature
- Agriculture

Drinking water companies in the Netherlands mainly abstract their water from the extensive groundwater reservoirs present. Additionally, they use surface reservoirs and infiltration of river water (ca. 30-40 %). The drinking water companies do not face major problems due to water availability or quality in the near future. However, a tool resulting in more efficient pumping can yield much profit. For other water users, water is not the core business, but a factor their products or activities largely depend upon. The revenues of the *transportation sector* are dependent on river stages, because the loading of ships is determined by water depth. *Electricity producing companies* and *major industries* are facing regulations to water use and should not exceed their license standards for both water quantity and quality. For *construction companies and project developers* water is one of the main aspects they have to take into account when designing new urban areas or infrastructure, and they therefore cooperate with municipalities and water boards. In *nature*, effects of water availability (incl. levels) and water quality on biodiversity are large, but nature still does not seem to get a high priority in the allocation of water. Traditionally, *agriculture* determines the water level in polder areas to a large extent by means of their influence in the water boards. Water availability and levels directly influence agricultural yield and revenues, while the economic value of natural areas is determined more indirectly by water. However, it is increasingly considered important, because nature does offer services which reflect economic value. All mentioned water users, although only indirectly dependent on water, increase profits or reduce economic losses by increasing the efficiency of their water-related activities. Better monitoring and forecasting systems that balance between water excess and shortage, are an important tool to achieve that.

2.3 Dutch water sector in perspective

The water sector currently is a reactive and quite conservative sector. Innovations in the sector are mainly technology push or research driven. For example, developments in tools and models for simulation of the water system are done by semi-governmental organizations like WL| Delft Hydraulics, TNO, and Alterra, after which possible clients in the water sector are approached. Major investments can be expected only when a certain system has proven its value. Therefore, successful pilot projects are extremely important to convince water managers and water users to invest in innovative systems and tools.

The water sector in the Netherlands is not unique in the sense that comparable situations, regarding both the physical and the administrative system, are present in delta areas around the world. Regions comparable to the Dutch situation include coastal areas and large river plains in most of Western Europe (Belgium, Germany, France, UK), but also the Danube and Wolga region and river plains in the Mediterranean region. Furthermore, most countries in Southeast Asia and extensive delta areas in the VS and South America, among others, are in many aspects similar to the Dutch water system. Some examples of regions that are very different from the Dutch situation include fjord coasts, like in Norway, Canada and New Zealand; permafrost areas in the Nordic region; desert areas in North Africa; and mountain regions.

3. Research organizations and programs

3.1 Research institutes

Wageningen University and Research Centre (WUR) consists of two parts: (1) Wageningen University and (2) DLO, a number of research institutes, of which Alterra is one. The Centre for Water and Climate (CWK) contains seven chair groups of Wageningen University and four groups of Alterra, all in the fields of meteorology, hydrology, earth system science, climatology, water management in various parts of the world, environmental system analysis, and ecohydrology/aquatic ecology. Some core funding of CWK is provided by the Dutch government, and additional funding is received from the Dutch Scientific Organization (NWO) that sponsors scientific research projects. On top of that, specific research projects of CWK are funded by governmental and commercial organizations and the EU (http://www.wur.nl/UK/about/facts+and+figures/Figures/).

CWK is a key player in the field of climate change and hydrological research, both nationally and internationally. In Annex 1 an overview is given of the relevant projects of CWK. Both recently finished, ongoing and future projects are included. The research done at CWK is innovative, and complementary to that of other research institutes. The focus of CWK is on land-atmosphere interactions, feedback loops, effect modeling, catchment hydrology, unsaturated zone monitoring and modeling, hydrological forecasting, ecohydrology and impact assessment for various sectors. The added value of WUR in a collaboration project lays in the area of protecting surface and subsurface bodies of fresh water and optimize the efficiency of their use.

The Royal Netherlands Meteorological Institute, KNMI, is the main Dutch research institute on the climate system, and, as it is a public entity, provides climate information and weather forecasts to users, be it governmental, research or commercial. KNMI contributes to many international networks (see hereafter) and its research is mainly directed to understanding and modeling the climate system, the feedback loops with the ocean, the land surface and aerosols. CWK and KNMI are important research partners in many projects.

Other partners of CWK in the field of climate and water are WL| Delft Hydraulics, TNO, GeoDelft (all three combined in the new research institute Deltares), Delft University of Technology, Utrecht University, Free University of Amsterdam, IHE, ITC, KIWA Water Research, KEMA, and internationally ECMWF, CEH (Centre for Ecology and Hydrology, UK), University of Oslo, and Max Planck Institute, among others.

3.2 National and European research programs

In the Netherlands a number of national programs and projects are devoted to climate change and adaptation. Here, an overview is given of the most relevant ones, in which KNMI and CWK are participating:

- BSIK: National research program in priority areas, among which:
  - Climate Changes Spatial Planning: Research on the climate system and the effects of climate change on spatial planning.
  - Living with Water: Research on the water system and the effects of climate change on hydrology.
- KvK, Knowledge for Climate (see Annex 3):
  - Hotspots: Priority areas for research and adaptation to climate change in the Netherlands (Mainport Schiphol, Rotterdam Port, etc.).
  - Climate Facility: Development of general modeling tools required by all hotspots to assess local effects of climate change.
- ARK, Adaptatie, Ruimte en Klimaat (= Adaptation, Spatial Planning and Climate): Implementation of adaptation measures in various sectors.

Within Europe many projects and networks exist that focus on climate and water research. The following are including CWK and/or KNMI:

- ECMWF EC-Earth Consortium in Europe: Earth system modeling.
- ECHAM: Max Planck Institute and partners: Weather and climate modeling.
- COSMOS Modeling Group: Community Earth System Models.
- EDC (European Drought Centre): Research and communication on droughts in Europe, more than 60 partners in Europe.
- FRIEND (Flow Regimes from International Experimental and Network Data), within the UNESCO-International Hydrological Programme: Observational network on flow regimes, more than 100 partners.

4. Climate and water modeling and observation system

The climate and water system is an extremely complex system. Research on components of that system has advanced considerably during recent decades, knowledge has increased and models on both climate and hydrology have improved. In this section the current system of climate and hydrological models will be explained and an inventory will be made of the shortcomings and research opportunities of the current system.

Figure 1 gives an overview of the system, independent on time scale, as both for short and long-term analysis the same model structure is used. Hydrological forecasts and information needed by water managers/ water users are based on hydrologic models run by the water managers/ water users themselves or by research institutes or consultancy firms. Dependent on the specific water manager or user the models can be groundwater models, surface water models, unsaturated zone models, water quality models, water temperature models, ecological models, or a combination of those. The input for these models consists of meteorological data, like temperature, precipitation, and evaporation. These data are derived from regional climate and weather models, run by the KNMI. The regional models are again based on global climate and weather models, run by ECMWF.

Observational data are used at various stages in this model chain. Meteorological data serve as input for the global and regional climate and weather models, and also directly for the hydrologic models. These hydrologic models are additionally fed by water quantity and quality observations for calibration. Prediction -of weather, soil moisture, hydrological events or impacts- requires a realistic characterization of the present status. This involves (near) real time data transfer from sensors to a central facility, online quality assessment, and a continuous analysis (model based interpolation) that is consistent with the prediction system. The end product, the description of the current situation, is as much data based as it is model based and the distinction between the two becomes vague. This is what is understood by 'data assimilation' in a generic sense. Such systems are relatively well developed in the meteorological community but much less so in the hydrology and/or impacts communities.

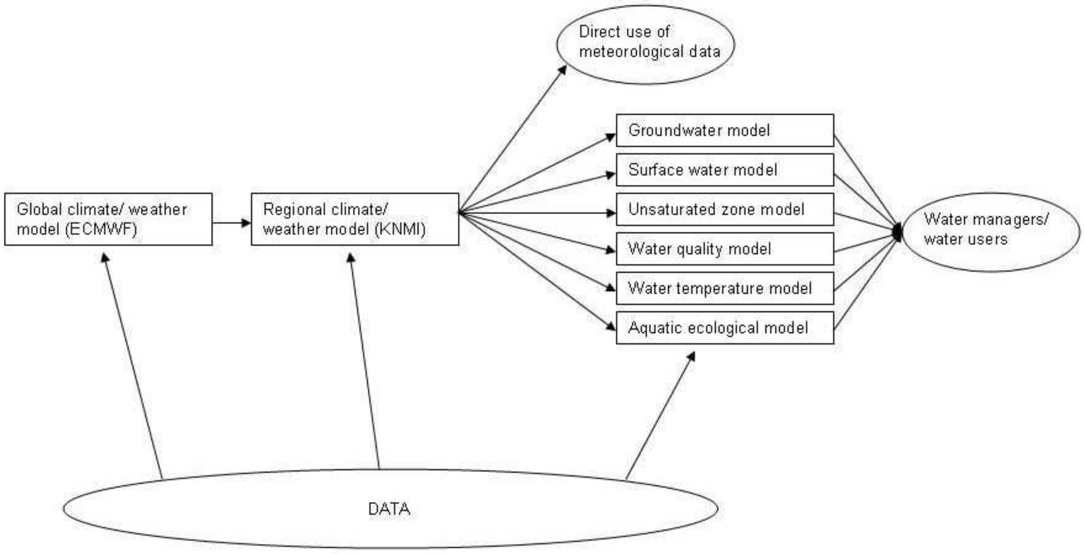

Figure 1: Overview of the system of climate and hydrologic modeling and the use of measurement data.

The shortcomings in the system occur at various levels:

- At the level of monitoring there is a trend to more, and more advanced sensor networking. However, measurement campaigns are still mostly set up by a water manager or researcher for a single purpose and directed to a single parameter. The challenge is to design multi-purpose sensor networks and to improve communication with data-centers and end-users so that every water manager can take out the information he/she needs.
- At the level of data analysis a common system should be set up based on GIS and visualization tools, in which water managers each have their own responsibility.
- At the level of simulation models and forecasting the bottleneck is computing power. Both for data assimilation, running the models, and doing scenario calculations the use of supercomputers or grids is essential, especially for real-time operational management.
- At the level of the use of data by water managers and water users a central control system focusing on dissemination of information and early warning is still missing. Such a system (comparable to the role of KNMI in weather) is extremely useful for both public and private organizations in the water sector.

A novel trend in such systems is that the same system can be used for characterizing the present status (now casting), for short term forecasting (~days-weeks), for seasonal forecasting (~months) as well as for long term (~years to decades) and scenario studies. This ‘seamless’ prediction concept , though scientifically in its infancy still, is extremely attractive from the point of view of data management, model development, analysis and visualization tools development, and thus ultimately resource management.

5. Key technical challenges

Based on interviews with water users, water managers and partner institutes (see Annex 2) urgent problems are identified that are considered critical to solve and that require technological innovation. These are large scale, complex issues that arise in a multi-client environment. The solution for these problems lies in innovative development of integrated, modular tools, in which each client provides funding for the module of its interest. In consultation with partner institutes two main focal areas have been defined that cover a large scale system. Additionally, a number of smaller scale urgent needs are identified focusing on a specific client (group) and a component of the climate and water system. These will be described in Section 6.

Main focal areas:

1. Improving water management in urban and peri-urban areas using tailor-made prediction and decision support information services
2. A comprehensive observation and modeling system for prediction and management of floods in delta areas like the Netherlands

5.1 Improving water management in urban and peri-urban areas using tailor-made prediction and decision support information services

The focal area on *Water management in urban and peri-urban areas* stems from the challenges regional water managers are facing and will be facing in the future. The climate scenarios for 2050 point to more extreme events, prolonged and more severe droughts, and more intense rainfall showers. Regional water managers will have to deal with that complex situation. At the moment, water management is predominantly reactive, while for the future a more proactive approach is needed. Water managers see an urgent need to develop tools to be able to anticipate extreme events, to do thorough risk analysis and to increase the efficiency of the water management system. A few examples of needs are derived from interviews with different players in the water sector:

- Water board Hollandse Delta: Blue Services, rent farm land where water can be stored in case of extreme rainfall and pay farmers for crop damage;
- Drinking water companies in Brabant: Further optimization of use of drinking water wells to protect drought-prone nature areas, based on drought prediction;
- City of Eindhoven: Operational management of the sewage system in the city based on detailed rainfall measurements;
- Dura Vermeer: Use of a real-time monitoring and prediction tool in innovative construction projects, like floating houses, and development of an early-warning system for inhabitants using for example SMS.

Decision making should be based on adequate information. Prerequisites are generation of the relevant local information and good dissemination of the information to the decision makers. Connection with the Dutch Knowledge for Climate (KvK) program (Annex 3) has an important added value, because in this program the *Climate Facility* focuses on the development of general modeling tools and the application of the results of these tools in water management. Furthermore, within KvK consortia are already put in place for specific hotspot areas. In this focal area the key objective is providing “Climate services”, tools to use climate and water information in proactive decision making.

Potential clients are (partly based on KvK consortia):

- Drinking water companies (Vitens, Evides, Waternet)
- Water boards (Hollandse Delta, De Dommel, Reest en Wieden, Waternet, Aa en Maas)
- Ministry of Spatial Planning
- Land users (agriculture, nature)
- Municipalities, especially those with plans for construction

- Project developers and contractors (i.e. Dura Vermeer)

The development of simple tools to include climate information in the decision making is essential for drinking water companies, water boards, and other regional water managers. They should be provided with tailor-made information and predictions that need no further adjustment to their specific situation. The most important focus points for the drinking water sector are the use of climate scenarios, sensor technology, use of online information on i.e. reservoirs and water temperature, use of weather and climate predictions at weekly and decadal time scale in hydrological models to have a firmer base for investment decisions. Soil moisture is a key parameter is these issues. The uncertainty in soil moisture observation and modeling is still very large, although it is an essential parameter because the effects on the climate system are enormous. Currently, new techniques are being developed based on remote-sensing that increase accuracy of observations. To be able to implement these improved observations in climate and hydrologic models big steps forward are needed. Self-learning software and coupling of climate models and hydrologic models are of key importance.

This focal area consists of smaller scale projects that run in parallel and all contribute to the long term goal of improving regional water management. In the end the separate projects will be combined to develop an integrated system in which each organization contributes to a specific part of the input or uses a specific part of the output. The system in which this is implemented is making use of the multi-input and multi-client environment to reach a better funded decision making. The complex technology required to build this integrated system is the challenge of the consortium.

Pilot area:
Regional water management pilot areas in the Netherlands, with a distinction between: (1) polder areas (peat and clay), and (2) free-draining, sandy upland areas. Up-scaling from polder/ regional level to national level.

Deliverables:
- real-time monitoring system of relevant parameters at regional scale
- coupling between observations, climate/ weather models and various hydrological models
- operational decision support system based on modeling and monitoring data

Partner institutes:
- KIWA (research organization of drinking water companies)
- STOWA (research organization of water boards)
- KNMI
- ECMWF
- IBM
- WUR

>> Implementation through: SARA (the Dutch national supercomputing facility in Amsterdam) and Waterschapshuis (Collaboration of water boards on ICT issues)

The value-add of IBM will consist of:
- Sensor networking
- Data streaming technology
- Self-learning models
- Computing power
- Visualization tools
- Large scale decision support system

5.2 A comprehensive observation and modeling system for prediction and management of floods in delta areas like the Netherlands

There is an urgent problem of increased flooding risk in delta areas, where most economic activity is located along the coast, alongside rivers and in other flood-prone, low-lying areas. Governments are forced to protect the people and business activities in these delta areas and therefore have a need for information as basis for their risk assessment.

This second focal area on *Flood prediction and management* is an extension of the Flood Control 2015 and SUCCESS projects and a combination with the ACER project. The focus of Flood Control 2015 is mainly on dike strength, but for an adequate flood prediction and prevention an integrated system is required, including monitoring and modeling of the entire river catchment and the analysis of the effects of climate change. The ACER project mainly focuses on long term developments such as climate change, socio-economic developments, spatial planning and policy developments that influence water management in the Rhine basin (see Annex 4). Within the ACER project an integrated Rhine model will be developed that should be combined with the Flood Control 2015 efforts to create an integrated system. Such an integrated system is composed of the following components:

- monitoring the Rhine catchment
- monitoring dike strength
- modeling the effects of flooding
- prediction of extreme flooding events
- early warning system for flooding
- use of climate information for flood management

A consortium of research institutes and IBM is suited to develop these technological components. The experience of IBM with *Deep Thunder* plays an important role and the Dutch *Knowledge for Climate* program (Annex 3) can add knowledge and modeling experience. The main requirements of the ACER project are currently computing power and coupling between models. The RAMS and VIC model are much too slow to use in real-time early warning systems, so more and better supercomputers are essential to make a step forward in using model tools. Furthermore, data-streaming between models and the use of observation data through self-learning techniques need much attention. In this focal area the focus lies on the development of an integrated tool.

Potential clients are:

- Public entities:
  - Ministry of Internal Affairs (security)
  - Ministry of Public Works and Water / Rijkswaterstaat
  - Provinces
  - Water boards
  - Municipalities
- Financial centers and insurance companies
- Major investors in trade and industry

For a first phase we can link up with the ACER project. For a second phase funding is initially provided by the governmental sector, because they are primarily responsible for providing security against flooding. However, investments of insurance companies and major industries are expected in parallel.

Pilot area:
Coastal area of the Netherlands and the catchment of the river Rhine.

Deliverables:
- integrated real-time monitoring system of relevant parameters at <u>catchment level</u> (rainfall radar, soil moisture satellites, etc. > NB: use of this kind of data can be subject to the Dutch licensing system: for a research project or phase data can be used free of charge, but commercial applications require a license)

- integrated real-time monitoring system of relevant parameters at dike level (water levels and dike strength)
- operational system for flood prediction and prevention based on modeling and monitoring data
- tool for dissemination of the information (use of the integrated system in the Flood Control Room)

Time frame:
The aim is to have the flood prediction system completely operational by 2015. Scientific and technological development of various projects will run in parallel. By 2015 the KvK research program will have reached its end and the *EC-Earth* project will be ready to deliver data that can be used in operational systems for the long term decision making. For the short term operational flood management ECMWF data will be used that will have improved significantly by 2015. Furthermore, the Dutch governmental policy strategy on water management *Room for the River* will end by 2015. The Ministry of Public Works and Water will have to develop a new policy strategy by that time, for which the developed flood forecasting and management tool can be a starting-point.

Partner institutes:
- Deltares:
  - WL | Delft Hydraulics
  - GeoDelft
  - TNO
  - Rijkswaterstaat
- KNMI
- ECMWF
- IBM
- WUR

>> Implementation through: SARA (the Dutch national supercomputing facility in Amsterdam)

The value-add of IBM will consist of:
- Sensor networking
- Real-time monitoring
- Data streaming technology
- Computing power
- Visualization tools

6. Short range projects

The inventory of the water sector additionally revealed a number of urgent specific technical needs. These are small scale, concrete, critical problems defined by specific water users where IBM technology could have a large value-add. The selected pilot projects can be implemented relatively fast and with clear applicable results. These are the client (groups) and their most pressing issues:

1. Waternet: observation and modeling of the entire water cycle to improve efficiency in regional water management in a densely-populated area.
2. Electricity generating companies: monitoring and prediction of river discharge and temperature for use as cooling water.
3. River transport sector: developing a monitoring tool of water depth to increase river navigability.
4. Nature and agriculture: developing a tool for drought multi-month forecasting and the effects on nature and crop yield through the water system.

6.1 Waternet

Waternet controls the entire water cycle in the city of Amsterdam and its surroundings (see Annex 5). To be able to accomplish its task, Waternet needs information as a basis for both its daily water management and its long-term investment decisions. Waternet is very eager to cooperate in a pilot project with IBM and research institutes, because they have a need for better climate information and predictions. More specifically Waternet asks for:

- More detailed, local information as a basis for daily operational management, i.e. an improved short term prediction (daily/weekly time scale)
- Less uncertainty in averages and extreme values in long term predictions (multi-decadal time scale) as a basis for investment decisions.

It would be a big challenge to direct this improved prediction at the entire water cycle, which falls completely under the responsibility of Waternet. The prediction tools that will be developed should be applicable to the preparation of drinking water, the sewage system, waste water treatment, and the management of the water system. As these systems have different information needs, the integrated system should be able to deliver fine-tuned information. This tuning of the data is of key importance.

To achieve the goals set by Waternet collaboration with KNMI is essential, because KNMI is the organization that is responsible for weather forecasts and climate predictions in the Netherlands. However, an outlook to the European scale will be achieved by including ECMWF and Max Planck institute. Furthermore, a connection is needed with the current sensor networks and modeling systems of Waternet. The challenge in this pilot project is to combine the existing systems to a useful integrated system and decision support tool.

The applicability of the developed integrated system reaches further than Waternet. The Union of Water Boards (the umbrella organization of the water boards) and a number of individual water boards expressed their interest in such a system. The business opportunities are widespread.

6.2 Energy sector

The production of electricity is of prime national interest, because a failing electricity system has a high economic and social impact. The cooling water system is very sensitive to drought situations with regard to water availability and water temperature. In the Netherlands strict regulations exist with regard to temperature of the discharged water. When not enough water is available or the water temperature is already relatively high due to drought conditions, power plants are shut down or switch to the use of cooling towers instead of cooling water from the river. Such a shut down or switch is extremely expensive. As drought situations will occur more often under climate change, economic losses of the energy sector are expected to increase rapidly. With better forecasting of future river flow and temperature changes better decisions on long term investments can be made. The electricity producing companies have shown great interest in the development of information systems for that purpose. They are very keen at participating in a project on the use of climate information in the prediction of cooling water availability and water temperature in rivers. A pilot project could be set up using a prediction tool and a comprehensive decision support system. Currently, research is being done at KEMA on the use of monitoring and prediction systems for the short term operational management of cooling water. But also for long term investment decisions on the location of power plants (for example for Electrabel and Essent), a tool is needed to predict the effects of climate change on availability and temperature of cooling water. Additionally, insurance companies (like Fortis) are increasingly interested in developing new insurance policies for the energy sector. The goal is that electricity generating companies using this insurance are being refunded for the economic losses due to shut down of a power plant. To be able to provide such an insurance a thorough risk analysis and accurate forecasts are of key importance. Consequently, Fortis and other insurance companies are eager to join a pilot project on this issue.

Another pressing issue regarding water in the energy sector is the fish that are sucked in with the cooling water. For the protection of endangered fish species and prevention of contamination of the filter, information on the location of fish shoals is very important. This problem is most urgent in estuaries, like the Waddensea in the Netherlands (Figure 2). These estuaries are very important breeding grounds for many species of fish, birds and other animals. The Waddensea has an official protected status within the European Union and a number of guidelines safeguard the fauna in the area. The industrial activities (power plants, other industries) in the Eems harbor all use the water from the Waddensea for cooling water and other activities and therefore are dependent on and have a large influence on the fragile ecosystem. A pilot project could be set up that is comparable to the *River Observatory Network* of the Beacon Institute, but is focusing on estuaries instead of rivers. Real-time monitoring networks for observation of parameters like water level, water temperature, salinity, oxygen content, biological activity, and fish migration, and the use of observational data for the operational management of the industrial activities in the Eems harbor are the main components of such a pilot project. Possible clients are the Port of Groningen, Groningen province, power plants and major industries in the Eems harbor area, and collaboration is needed with NIOZ (Royal Netherlands Institute for Sea Research) and WUR IMARES (Institute for Marine Resources & Ecosystem Studies). Connecting with the Knowledge for Climate hotspot on the Waddensea (see Annex 3) has an important added value.

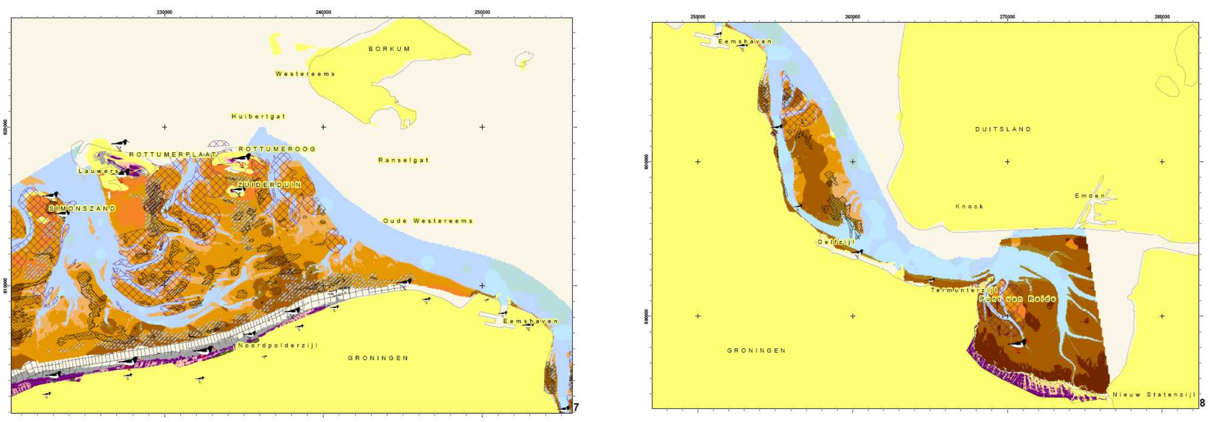

Figure 2: Biological activity in the eastern part of the Waddensea, where the Eems harbor is located (source: http://documents.plant.wur.nl/imares/ecologische_atlas.pdf).

For both pressing issues the technological needs come down to the following: sensor technology, computing power, and data streaming technology. KEMA, KNMI and Rijkswaterstaat are the most important research partners and the expertise of IBM is essential in developing the required tools. The first phase clients are a number of Dutch electricity generating companies (Essent at Meuse river and Electrabel at Rhine river and Waddensea), but the applicability of the tools reaches much further to other power plants that are dependent on river or estuary water for cooling, e.g. in France, Italy, UK.

6.3 River transport sector

The major industries in the Rotterdam harbor area are completely dependent on the navigability of the rivers for their connections with the rest of continental Europe. At present, a large safety margin is applied, because detailed and reliable information is lacking. Therefore, ships are not loaded efficiently, and much can be gained by better tuning the ships loading to real-time water depth. Interviews have revealed the interest of the Port of Rotterdam and their customers, the industry and trade sectors, in collaboration.

Innovative technological developments are needed to provide detailed and reliable information that is required. Components can be; (1) the use of satellite remote sensing to detect water depth (big steps forward are being made in that field), and (2) equipping ships with sensors to get a dense measuring network in the river. Both techniques are at the moment only used at sea or at large rivers like the Amazon, but there is a large need to apply them also to smaller rivers. The combination of these measuring techniques with a visualization tool pose a large technological challenge in which IBM is of key importance. A next step would be the development of a tool to deliver detailed forecasts of water depths on a weekly time scale.

On the longer term (multi-decadal time scale) the effect of climate change on the navigability is also gaining interest. In Germany a large study on low flows is currently being done. Questions like: what are the problems arising in the hinterland?, what will be the economic losses?, who will pay for the damage? are being posed by navigation companies and major industries. Currently, a Knowledge for Climate project on these financial aspects is proposed by the Free University Amsterdam. However, these analyses can not be done without accurate knowledge of the river system and the effects of climate change. So, multi-decadal climate projections of KNMI should be combined with navigability tools. This has never been done and requires innovative software and streaming techniques.

Not only the shipping industry and the Port of Rotterdam are keen on developing these tools, also the dredging companies have shown their interest. When they have a detailed and up-to-date map of water depth at there disposal, dredging can be done far more efficiently and investments in dredging can be lowered significantly. The Port of Rotterdam, however does not see these activities as their responsibility, but points to Rijkswaterstaat as the responsible organization.

6.4 Nature and agriculture

Over the centuries, nature in delta areas, like the Netherlands, has been adapted to rather wet conditions. Since the middle of last century large Dutch areas have been drained because it used to be too wet for optimal agricultural crop growth and mechanized farm operations. The large-scale drainage led to drying out of many wetlands and water tables even dropped too low for agricultural crops, especially during droughts. As a response, Dutch farmers started to use supplementary irrigation. Excess water during wet periods causes more damage to agricultural crops than water shortage. Hence, excessive drainage was implemented and rather deep water tables were accepted. These developments had a detrimental impact on the remaining wetlands. The last decades of the 20th Century the policy had to be revisited due to societal pressures. Water management and agricultural practices had to change (acceptance of sub-optimal conditions) to save the last wetlands and deteriorated wetlands had to be restored to increase biodiversity again. In 2015 the water system of over 270 nature reserves has to be back in the original state, implying that almost 100.000 ha have to be restored. Possible measures are stopping of groundwater abstraction, filling in of drainage ditches, raising of surface water levels, financial compensation of farmers to accept damage to excessive water.

This large-scale operation requires a fine-tuned and area-tailored water management, including spatial differences, that offer optimal conditions for nature development and agricultural production systems that are adapted to these wetter conditions, but still have to be economically viable. This is a major challenge, in particular because inter-annual weather is variable and the response time of the water system is rather long. In addition, it is likely that climate change will lead to a even more dynamic situation, i.e. to more extreme storms and more severe droughts. A sense of urgency is present in nature conservation agencies and agricultural organizations. For example Staatsbosbeheer (one of the largest nature conservation agencies in the Netherlands) expressed an urgent need for better prediction systems for drought. Multi-month up to seasonal forecasts with a almost continuous update are needed for optimal water management. Their requirements for such a prediction system mainly consist of better data streaming techniques, the coupling of weather forecasting models, hydrological models, and impact models for nature and crop yield, and comprehensive visualization techniques. In addition to these tools, cheap sensors need to be developed and installed to monitor highly-spatial state variables (soil moisture, groundwater levels, surface water levels) and fluxes (precipitation, steamflow). These ground-based sensors need to completed for the spatial coverage with airborne data (precipitation, evapotranspiration, soil moisture, crop and vegetation growth). The modelling, monitoring and forecasting system need to be fully integrated and imbedded in a user-friendly decision support system. Possible clients for such a system are the Ministry of Agriculture and Nature Management, agricultural organizations, and nature conservation agencies. Investments are expected due to the increasing pressure on these organizations to accomplish the goals for 2015.

7. Challenges and opportunities for cooperation

The water sector uses climate and weather information in its decision making and has advanced measuring techniques and modeling tools. However, still much is missing as basis for both long term investment decisions and short term operational management. To be ready for future climate and extreme weather events a proactive approach is needed that requires innovative technology of both hardware and software. Consultation of water managers and water users revealed many pressing issues and needs, resulting in a high number of possible pilot projects.

Two most promising large scale areas, and four smaller scale technical needs, are elaborately described in this position paper. The possible pilot projects focus on the development of a transferable system, using a core modeling system (see Figure 3). This would greatly enhance its adoption by other clients in the same sector, and thus its commercial attractiveness. This applies both for clients in the Netherlands as well as abroad.

During the following phase of the exploration of IBMs business opportunities in the climate and water sector, discussions should point out on which pilot projects we will focus and which consortia we will form. After choosing a focus, we should elaborate the proposal for pilot project(s) together with the specific client (group) and research partners involved, and make their investment intentions more concrete. One or more early-wins are within reach, with contribution of the ongoing Climate Changes Spatial Planning, and Knowledge for Climate programs. The clients in the water sector are very eager to start working on these innovative pilot projects to be prepared for the effects of changing climate on the water system.

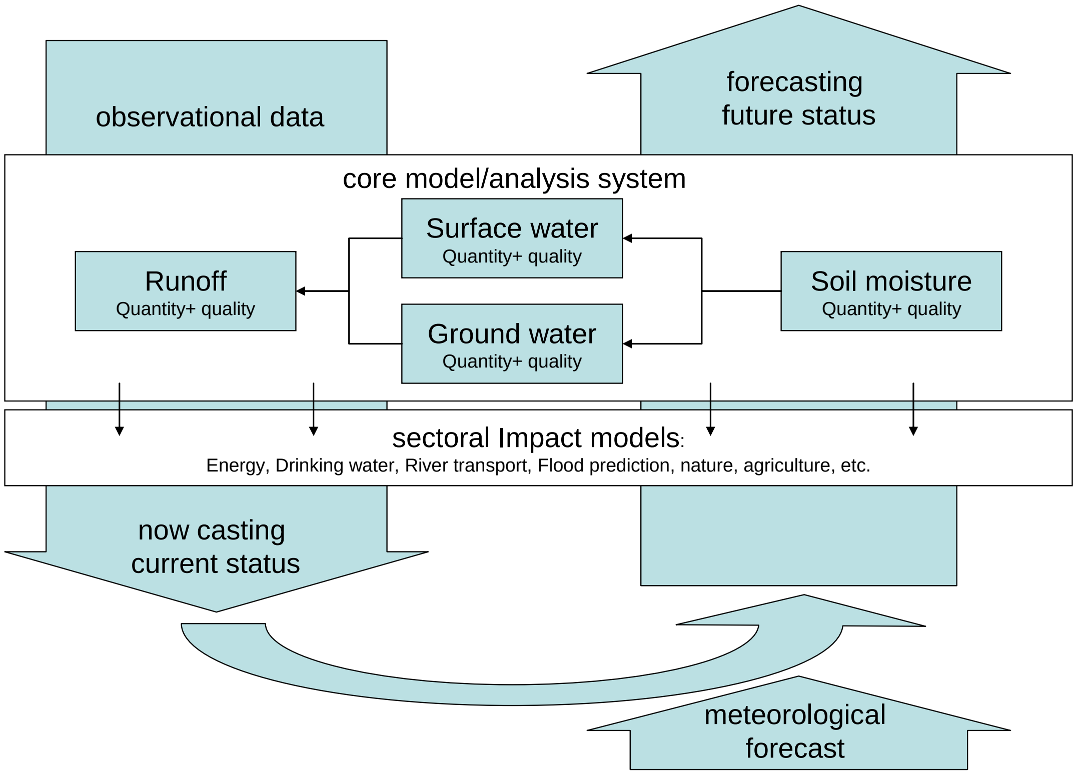

Figure 3: Overview of the core modeling system.

Abbreviations

WUR = Wageningen University and Research Centre
CWK = Centre for Water and Climate, WUR
KvK = Knowlegde for Climate (Kennis voor Klimaat)
KNMI = Royal Netherlands Meteorological Institute
ECMWF = European Centre for Medium-range Weather Forecasts

Annex 1:

Relevant finished projects

Acronym	Description	CWK staff involved	partner organisations	opportunities IBM project
ARIDE	Assessment of the Regional Impact of Droughts in Europe	van Lanen	- Univ. of Freiburg - Centre for Ecology and Hydrology - Univ. of Oslo - Centro de Estudios y Experimentación de Obras Públicas, Madrid - Instituto da Água, Lisbon	• drought types; • near real time drought monitoring and prediction; • drought generating processes; • drought regionalisation
ASTHyDA	Analysis, Synthesis and Transfer of knowledge and tools on Hydrological Drought Assessment through a European network	van Lanen; Querner	-Univ. of Oslo -Univ. of Freiburg -Centre for Ecology and Hydrology; - IRD – Hydrosciences, Montpellier; - Comenius Univ., Bratislava; - Norwegian Water Resources and - Energy Directorate, Oslo; - TGM Water Res. Institute, Prague; - Danish Hydraulic Institute; - Water Problem Institute, Moscow; - Jan Kochanowski Univ., Kielce - Univ. of Canterbury, New Zealand; - Univ. of British Columbia, Canada	• hydroclimatology; • drought generating processes; • data; • drought types – indicators; • prediction – probabilities at site and regional; • attribution human influences; • operational – links with sectors
DAUFIN	Data Assimilation within Unifying Framework for Improved river basin modeling	Torfs	- Centro di Ricerca, Cágliari; - Ente Autonomo del Flumendosa, Cágliari - Space Applications Institute, Ispra; - Institut Royal Météorologique, Bruxelles; - Univ. of Liège; - Warsaw Agric. Univ.; - Regional Water Development Authority, Wroclaw	• data assimilation; • water resources management; • new watershed modeling approach
VOLTAIRE	Validation of Multisensor Precipitation Fields and Numerical Modelling in Mediterranean Test Sites	Uijlenhoet	EU-FP5	• sensor networks • modeling

CC & infrastructure	Effects of climate change on infrastructure and information requirements of the sector	Van Hove		• inventory on needs of specific sector; • effect analysis

Relevant ongoing projects

Acronym	Description	CWK staff involved	partner organisations	opportunities IBM project
FLOODsite	Integrated Flood Risk Analysis and Management Methodologies	Uijlenhoet	EU-FP6 IP: 44 partner institutes	• flood prediction
WATCH	Water and Global Change	Van Lanen; Kabat; Hutjes; Van Loon	EU-FP6: - Centre for Ecology and Hydrology; - Free Univ. of Amsterdam - Danish Meteorological Institute; - CEMAGREF; - Univ. of Frankfurt; - Int. Centre for Theoretical Physics –Triest; - UK Met Office - Hadley Centre; - Max Plank Inst. for Meteorology, Hamburg; - Polish Academy of Science; - Potsdam Inst. for Climate Impact Research; - Technical Univ. of Crete - Univ. of Oslo; - Univ. of Valencia; - Univ. of Oxford; - IIASA - Int. Inst. for Applied Systems Analysis; - Laboratoire de Meteorologie Dynamique, Paris; - Univ. of Lisbon; - Comenius Univ., Bratislava; - Consejo Superior de Investigaciones Científicas, Barcelona; - Univ. of Kassel; - KIWA, Netherlands ; - Observatoire de	• link of climate and water • past (20^{th} C) climate • future (21^{st} C) climate; • feedbacks climate and water • data; • droughts; • large-scale floods; • water resources; • operational – sectors (river basins/cases) • coherent suite of prediction tools; • uncertainty assessment methodology.

			Paris; - TGM Masaryka Water Research Inst., Prague; - Norwegian Water Resources and Energy Directorate, Oslo.	
HYDRATE	Hydrometeorological data resources and technologies for effective flash flood forecasting	Uijlenhoet; Hazenberg	EU FP6 STREP: 17 partner institutes	• flash flood prediction
NeWater	IWRM and adaptive management	Kabat; Hurkmans; Uijlenhoet		• water modeling
CarboEurope	Assessment of the European Terrestrial Carbon Balance	Kabat; Moors		
SCENES	Water Scenarios for Europe, 2006-2009	Kabat;		
AquaStress	New approaches to mitigating water stress	Moors; Froebrich;		
Heterogeneous flow and transport modeling	flow and transport in heterogeneous aquifers, with biogeochemical interactions	Van der Zee; Groenendijk	- UFZ - TUE - Univ. Stuttgart - UFZ	• high power computing • requires excessive computation times and memory • flow modeling
Salt water intrusion modeling	flow and transport in heterogeneous aquifers, with biogeochemical interactions	Van der Zee; Leijnse	- TNO - TUE - Univ. Stuttgart - UFZ	• high power computing • requires excessive computation times and memory • flow modeling
combining flow, transport and chemistry modeling	combining modules in object oriented fashion, the future of reactive transport modeling	Van der Zee; Leijnse	- ECN - Univ. Stuttgart	• high power computing • flow modeling
Observation and parameterization of the hydrological component of land surface - atmosphere interactions	"Monitoring and profiling with the Cabauw Experimental Site for Atmospheric Research"	Bokhorst; Uijlenhoet	- project partners within BSIK Climate Changes Spatial Planning	• Dutch national atmospheric and land surface remote sensing facility • Advanced groundbased remote sensing techniques
ACER	Impact of climate change and land use changes on Rhine discharge and flooding	Hurkmans; Uijlenhoet		
POT	Developing a	De Rooij;	- Universiteit Twente	• real time data

	polymer tensiometer to measure water stress in cropped soils	Gooren; Van der Ploeg	- Ecoceramics B.V. - Keller Instruments - Enrin (Environmental Research Instruments)	processing • integration of sensor network technology and processing software • expert systems development for irrigation scheduling

Relevant future projects

Acronym	Description	CWK staff involved	partner organisations	opportunities IBM project
XEROCHORE	Exercise to Assess Research Needs and Policy Choices in Areas of Drought	Van Lanen;. Kabat;. Leemans; Wegerich	- Univ. of Oslo; - Centre for Ecology and Hydrology; - Fondazione Eni Enrico Mattei, Milan; - Water Management Center GbR, Hannover - Ministero dell'Ambiente, della Tutela del Territorio e del Mare, Italy; - Ministerio de Medio Ambiente, Madrid; - National Technical Univ. of Athens; - Joint Research Centre, Ispra - Centre National du Machinisme Agricole, du Genie Rural, des eaux et des Forets, CEMAGREF, France ; - Int. Union for Conservation of Nature and Natural Resources	• droughts • tuning of approach; • natural system (climate and water); • management – sectors; • link sectors and policy
Rainfall measurement using radio links from cellular communication networks	real-time construction of rainfall maps with a country coverage using radio links from cellular communication networks	Leijnse; Uijlenhoet	- KNMI; - commercial telecom provider	• smart sensor networks • "real-time" applications
Climate models & atmospheric chemistry	coupling of models dealing with the climate system and atmospheric chemistry	Ganzeveld	- SARA	• climate modeling
EU proposal on Earth System		Kabat	- KNMI; - Hamburg;	• modeling

Modeling			- ECMWF	
Improving irrigation efficiency	use of polymer tensiometers in irrigation projects, aim: to save significant amounts of irrigation water	De Rooij		• sensor technology • sensor networks

Annex 2:

Steering committee CWK

Organization	Person
WUR-CWK	Pier Vellinga Pavel Kabat Wim Cofino Remko Uijlenhoet Eddy Moors Henny van Lanen Sjoerd van der Zee Laurens Ganzeveld Ronald Hutjes Ger de Rooij Bert van Hove

List of interviewed organizations & people

Organization	Person
IBM	Gary Rancourt Harry Kolar Lloyd Treinish
IBM the Netherlands	Jan Blommaart Djeevan Schiferli
WUR-CWK	Pier Vellinga Remko Uijlenhoet Eddy Moors Laurens Ganzeveld Ger de Rooij Bert van Hove Cor Jacobs Ruud Hurkmans
KNMI	Wilco Hazeleger
Rijkswaterstaat / RIZA	Leonie Bolwidt
KIWA	Wim van Vierssen Gertjan Zwolsman
Deltares	Harry Baayen Ipo Ritsema (TNO) Harm Aantjes (GeoDelft)
Waternet	Theo Janse Joost Kappelhof
Port of Rotterdam	Rinske van der Meer
Electrabel	Marco van Beek
KEMA	Henk Jenner
TNO	Kees van Deelen Mart van Bracht
SARA	Axel Berg
Dura Vermeer	Cris Zevenbergen Steven de Boer
Water board Hollandse Delta	Hans Waals
Union of Water Boards	Rein van der Kluit
MNP	Lex Bouwman
Staatsbosbeheer	Cris Kalden

Annex 3:

Summary Knowledge for Climate program

Knowledge for Climate (KvK; Kennis voor Klimaat) is a government funded research program focusing on climate change and adaptation. 50 M € is allocated for research in eight regional hotspots, for a project called Climate Facility and for international collaboration.

- Hotspots, where climate proofing is needed:
  - Haaglanden: Area around The Hague, which has a high contribution to the Dutch economy and faces serious threats of sea level rise and flooding in urban areas.
  - Mainport Schiphol: Airport Schiphol is located in a deep polder (4-6 m below MSL) and will have to cope with water-related problems in the future.
  - Rotterdam: The Port of Rotterdam and the shipping industry are involved in this project to evaluate the effect of changing climate on the harbor and river area.
  - River regions: Major rivers in the Netherlands that need more security against flooding in the light of climate change.
  - Southwest Delta: Region in which adaptation to climate change deserves much attention.
  - Dry, rural areas: The higher rural areas in the east of the Netherlands will have to cope with more extreme rainfall and drought events, adaptation is needed.
  - Waddensea: The ecosystem of the Waddensea estuary is in need of applicable knowledge on the effects of climate change.
  - Shallow lakes and peat areas: The fragile ecosystem and decreasing elevation in these areas calls for research.
- Climate Facility: Support the hotspots with local climate scenarios and water-related information based on modeling exercises. Modeling software will be developed by a consortium of KNMI, TNO-Deltares, UU and WUR.
- International collaboration within KvK is directed to the applicability of the KvK results and knowledge to comparable regions and systems elsewere.

Annex 4:

(http://ivm5.ivm.vu.nl/adaptation/project/acer/)

ACER Project context and goals

The ACER project aims at identifying how long term developments such as climate change, socio economic developments, spatial planning and policy developments influence water management in the Rhine basin. The project develops an integrated Rhine model that enables quantifying the effects of long term trends on the frequency and magnitude of floods and droughts in the Rhine. An important issue will be to assess changes in future flood and drought probabilities.

Different water management strategies (dikes, retention, land use change, insurance, etc) will be developed to cope with future impacts. The strategies are targeted at areas in both Germany and the Netherlands and will be developed with stakeholders from both countries in a series of workshops.

The strategies will be evaluated as to how they mitigate extreme events and lower risk (probability * damage) in especially the NiederRhein area at the border of Germany and the Netherlands.

Products:

1. **Scenarios:** A set of scenarios that include climate change, socio economic developments, land use change and institutional changes such as the effects of the EU flood directive.
2. **Basin Adaptation Strategies**: New cross boundary adaptation strategies to mitigate extreme events (floods and droughts) in the Rhine basin under climate change. The strategies will explore the effectiveness of retention upstream, land use changes, changing dike elevations and risk diversification.
3. **Regional Adaptation strategies** for the regional water boards that include specific spatial planning measures for local water managers such as water buffering and land use change.
4. **A Rhine model:** Based on existing models that exist for parts of the Rhine, a new coupled atmospheric-hydrological model will be developed describing both the energy and water balance for the whole Rhine basin. The model enables simulating adaptations related to land use changes and provides accurate information on the timing of extreme events. The model is based on the **RAMS** , **VIC** , **HBV** and **SOBEK** models.
5. **Evaluation:** An integrated risk analysis of the basin wide and regional adaptation strategies using multi criteria analysis.

Annex 5:

Schematic Water chain