1 REGISTRATION

1A. Programme characteristics

research theme

☐ Theme 1 Water safety at national and regional level
√ **Theme 2 Fresh water supply and water quality at national and regional scale**
☐ Theme 3 Climate proofing rural areas
☐ Theme 4 Climate proofing urban areas
☐ Theme 5 Infrastructure and networks
☐ Theme 6 Improving climate projections and the set of instruments used for modelling
☐ Theme 7 Governance of adaptation
☐ Theme 8 Decision support tools

number of work packages: 6

duration of the programme: 4 years and 3 months (max. 51 months)

number of appendices

10	track records of involved research groups (appendix 3)
17	CVs of leading researchers (appendix 4)
5	letter of cooperation and commitment foreign research partner(s) (appendix 5)
9	letter(s) of intent for co-funding (appendix 7)

1B. Main applicant

Consortium partner	Knowledge institute	Name, titles and affiliation
Main applicant *	Deltares	Prof. ir. E. (Eelco) van Beek Water Resources Management specialist; Scenario and Policy Analysis
Address	Rotterdamseweg 185	
Postal code and place	2629 HD Delft	
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Tel.number	+31 15 285 8419	
E-mail	Eelco.vanBeek@deltares.nl	
By signing this form, the main Applicant on behalf of all consortium partners states that (parts of) this research proposal has not been submitted for funding elsewhere.		
Signature		
Date	January 5, 2010	

* the main applicant is contact person and consortium leader

1C. Composition of the research consortium

Contributing knowledge institute (name, address)	Research group and leading researchers
1 Deltares P.O. Box 177 2600 MH Delft	Scenario and Policy Analysis - Prof. ir. E. (Eelco) van Beek (WP-1) - Dr. ir. A.B.M. (Ad) Jeuken Subsurface and Groundwater Systems - Dr. ir. G.H.P. (Gualbert) Oude Essink (WP-2)
2 Wageningen University Droevendaalsesteeg 4, PO Box 47 6700 AA Wageningen	Soil Physics, Ecohydrology, and Groundwater Management - Prof. dr. ir. S.E.A.T.M. (Sjoerd) van der Zee (WP-3)
3 KWR, Watercycle Research Institute P.O.Box 1072 3430 BB Nieuwegein	Department of Water Systems - Prof. dr. P.J. (Pieter) Stuyfzand (WP-4) - Prof. dr. ir. J-P. M. (Flip) de Witte - Dr. J.J.G. (Gertjan) Zwolsman - Dr. ir. M.A.A. (Marcel) Paalman - Dr. E.R. (Emile) Cornelissen
4 VU University of Amsterdam De Boelelaan 1085 1081 HV Amsterdam	Department of Hydrology and Geo-environmental Sciences - Dr. V.E.A. (Vincent) Post Department of Systems Ecology, Institute of Ecological Science - Prof. Dr. J. (Jelte) Rozema
5 University of Twente P.O. Box 217 7500 AE Enschede	Water Engineering and Management - Prof. dr. A. (Anne) van der Veen
6 Alterra, Droevendaalsesteeg 3, P.O. Box 47 6708 PB Wageningen	Earth System Science and Climate Change - Ir. J.A. (Jeroen) Veraart (WP-6) - Drs. S. (Saskia) Werners Integrated Water Resource Management - Ir. R. (Robert) Smit Ecological Models and Monitoring - Dr. M. (Maurice) Paulissen Note: the last 3 researchers are not included in Appendix 4
7 Delft University of Technology, Jaffalaan 5 2628 BX, Delft	Technology, Policy and Management - Prof. dr. ir. W.A.H. (Wil) Thissen (WP-5)
8 Acacia Water Jan van Beaumontstraat 1 2805 RN Gouda	Acacia Water - Dr. J. (Koos) Groen - Dr. A.C. (Arjen) de Vries
9 Utrecht University, Heidelberglaan 2, 3584 CS Utrecht	Copernicus Institute for Sustainable Development and Innovation - Dr. J.P. (Jeroen) van der Sluijs
10 TNO Built, Environment and Geosciences, Laan van Westenenk 501, 7300 AH Apeldoorn	Environment, Health and Safety - Ir. R.J.M. Creusen

Foreign research partner(s)* (name, address)	Research group and leading researcher
ASR Systems, Gainesville, Florida, USA	Dr. David Pyne
British Geological Survey Keyworth Nottingham NG12 5GG United Kingdom	National Environment Research Centre, Geophysical Tomography Team - Dr. R.D. Ogilvy
EPFL (Ecole Polytechnique Federal Lausanne), GR C1 565 Station 2, CH-1015 Lausanne, Switzerland	Hydrology and Water Resources - Prof. Dr. A. Rinaldo
Federal Institute of Hydrology (BfG), Am Mainzer Tor 1, 56068 Koblenz, Germany	Department M2 - Water Balance, Forecasting and Predictions - Dr Thomas Maurer
Institute National de Recherche en Genie Rural, Eaux et Foret (INRGREF), Tunisia	Dr. Fethi Bouksila
United States Geological Survey (USGS), 3110 SW 9th Avenue, Fort Lauderdale, Florida, U.S.A.	Florida Integrated Science Center - Dr. Christian Langevin
Other knowledge-generating institutes	**Department and leading researcher**

* letter of cooperation and commitment signed by the main applicant and the foreign research partner(s) is included in Appendix 5, except the letter of BfG which has not reached us yet.

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2 MAIN CHARACTERISTICS

2A. Titles

Full title of the full proposal
Towards a climate proof fresh water supply: robust and flexible solutions to balance supply and demand of quantity and quality on different scales
Short title of the full proposal (max. 5 words)
Climate proof fresh water supply
Titles of work packages (min. 3 – max. 7)
WP-1 Climate change in the Netherlands in a global/European perspective - our boundary conditions WP-2 Adapting fresh water supply and buffering capacity of the coupled groundwater–surface water system WP-3 Adaptation and implications of increasing salt water pressures to agriculture and nature WP-4 Water technology as a tool for sustainable regional water supply WP-5 Decision making under uncertainty – finding a robust and flexible fresh water supply strategy WP-6 Integrating cases

2B. Summary and overview of the programme

2B1 Summary of the full proposal (max. 300 words)

Climate change will affect the supply of fresh water to populations and economic sectors in many deltas around the world. Also the Netherlands will have to adapt to a growing mismatch between water demand and supply.
The central question is: what are opportunities and adaptation strategies for fresh water supply and water quality in the Netherlands, given the changing physical boundary conditions in evaporation, precipitation, river discharges, sea level rise and salt water intrusion? The focus is on regional and local solutions within the low lying parts of the Netherlands. In addition to droughts, the main threat to fresh-water availability in this area is salinisation. The proposed research focuses on how these regions can become more self reliant but also on what adaptation within the main (Rijks) water system can contribute to the region.

Regional strategies and measures are investigated in three directions: improving buffering and allocation of fresh water within the region by water management; using water technologies like underground storage, desalination techniques and re-use of local available sources (e.g. waste water); and adaptation of land use, agriculture and nature, to changing fresh water availability. Three case study areas are selected in agreement with the involved hotspot parties: 'Haaglanden' (fresh water supply for greenhousing and industry), 'Zuidwestelijke Delta' (horticulture and (underground) waterstorage) and 'Groene Ruggengraat' (nature and agriculture under increasing salinisation and droughts). Field measurements and modelling within the work packages directly focus on these three areas. In addition to research on specific measures, the hotspots will be supported to develop integrated robust and flexible strategies for fresh water supply for the case study areas. These integrated strategies not only contain a technical component but will also involve guidelines for dealing with uncertainty associated with the problem of droughts and salinisation. Both the physical system and the governance system are considered, the latter in close cooperation with KfC themes 7 and 8.

2B2 Overview of main research questions on three levels (max. 750 words)

On the level of the overall theme

The main research questions on a general level are:

- what is the potential of measures to either increase water availability or decrease water demand.
- how can effective regional adaptation strategies be built from these and other measures.

- and to what extent do these strategies contribute to a national solution for a climate proof freshwater supply?

On the level of work packages and projects

In **WP-1** there are two main research questions:

- What conditions (evaporation, precipitation, river discharges, sea level rise and related salt water intrusion) can be expected in the Netherlands as a result of climate change but also as a result of decisions on water management within the Rhine basin. In the associated project the main research questions are: can new techniques, using ensemble predictions, statistics derived from long multiple year time series (opposed to individual characteristic years) provide better insight in boundary conditions and connected uncertainty. In addition to climate uncertainty what may be the possible effect of water management measures within the Rhine and Meuse basin.
- In addition how may the economic vulnerability or resilience of sectors depending on fresh water develop on different scales (international to the level of individual companies). The two most interesting scales are the international and local level. On the international level the question is: how may the Dutch agricultural sector develop compared to its international competitors under a changing climate? On the local level the question is how is the economic drought risk is perceived and what the prospects are to act.

WP-2 is focussed on the question: How will the spatiotemporal patterns in the fresh water availability in ground- and surface water in coastal lowland regions change due to climate change and what adaptation strategies can be implemented to sustain water-dependent functions in the future? The two projects in this work package aim at answering the research questions:

- What are the controls on the interaction between groundwater and surface water during dry periods that determine the spatiotemporal dynamics in water quality and how can these be represented in models? This understanding is vital to to quantitatively evaluate possible adaptation strategies.
- How do fresh water lenses in brackish-saline environments at different levels react to climate change and adaptation strategies, what are key factors, and how can results derived in case study areas be extrapolated to other regions?

WP-3 is focussing in three projects on three main questions:

- How salt tolerant are conventional and ‘saline’ cultures and natural vegetations?
- How should this dependency be quantified to account for the complexity of environmental conditions, non-chronic exposure to salt, soil types, geohydrology, and plant specific factors?
- How can we benefit optimally from differences in salt tolerance with regard to agri/horticultural and ecosystem management, ecosystem protection and restoration strategies, crop rotation schemes, fresh water allocation and saving, and specialized high profit markets?

WP-4 is investigating the potential of water technology for providing solutions for regional self-sufficiency in the fresh water supply in two projects. The first project is focussing on the LSR-ASR (Leaky Storage Reservoir combined with phreatic Aquifer Storage and Recovery) system, addressing questions like:

- What are the hydrological and chemical effects of LSR-ASR systems during the filling, storage and recovery stage, how can these effects be mitigated?
- How can a LSR-ASR system be optimized in order to also form a buffer against extreme annual anomalies in either supply or demand?
- How can ASR systems be combined with other uses (e.g. to store and recover desalinized water or water supply for cooling and/or heating purposes)?

In a second project questions are elaborated like:

- What is the availability and quality of the alternative water resources, and which purification techniques can be applied to make them fit for agricultural or industrial use?
- Are innovative desalination techniques feasible along with more common desalination techniques?
- How can we dispose of membrane concentrate (brine)?

WP-5 addresses the main question: how can the various uncertainties encountered when developing policies for long-term fresh water supply best be dealt with? Sub-questions which are elaborated in the projects include:

- What are the relevant uncertainties in characteristic regional fresh water supply situations to be dealt with in the Netherlands? What is their character, and how important are they?
- What analytical approach best suits the different uncertainties?
- what criteria can be relevant for choosing among these policy options, with a particular view to how they deal with uncertainties (flexibility? Least-regret? Robustness?)
- what general recommendations can be given for the selection of a preferred policy strategy to deal with uncertainties, depending on the situation characteristics?

In **WP-6** three integrating case studies are carried out. Central research questions in each case study are:

- Problem framing: do the involved scientists, practical experts and regional policy perceive the (growing) mismatch between freshwater supply and demand? What is the level of (dis)agreement about the sense of urgency to tackle this issue?
- Joint fact finding: what are the physical and socio-economic key indicators for climate proofing water supply, water use and impacts on the water balance?
- Co-production of knowledge: Designing and tailoring regional explicit adaptation strategies, including portfolios with measures to cope with salt and drought risks and to capitalise on new opportunities
- Joined evaluation of alternative strategies: identification of the (perceived) level of ‘no-regret’ of proposed strategies/measures

3 SCIENTIFIC ASPECTS

3A. Description of the research programme (max. 2500 words)

3A1 Problem definition, aim and central research questions

Problem definition

The latest climate impact assessments show that climate change will cause an increasing mismatch between demand and supply of fresh water in many densely populated deltas around the world. This mismatch is a result of more frequent droughts, lower summer river discharges and increasing salinisation associated with changing atmospheric circulation, precipitation patterns and sea level rise. These trends not only influence the water supply but also the demand.

Recent studies for the Netherlands also show that the current water supply strategy is not climate proof in the long term. A future 'climate proof' fresh water supply therefore has become a national top priority on the Dutch water policy agenda.

Conventional strategies in the Netherlands rely on the intake of fresh surface water from the rivers Rhine and Meuse. This water is used to replenish regional surface water lost to irrigation, evaporation and infiltration to the groundwater system. Large amounts of intake water are used to dilute surface waters and to mitigate the effects of saline groundwater seepage. These conventional strategies may not be robust, as river discharges become more erratic, salt water wedge from the sea intrudes further upstream rivers, water demand intensifies in drier growing seasons and saline groundwater seepage in low-lying areas with controlled water levels (and confronted with ongoing soil subsidence) increases. Also if current trends in the agricultural sector continue the demand for good quality water will increase further. This affects many vital economic sectors, ranging from local to national level. The importance and urgency of this problem is underpinned by policy statements from the Delta Committee and the draft National Water Plan.

In the call for proposals the following main (hotspot) questions were identified:

A. How can fresh water supply be robustly designed in order to be flexible in anticipating a wide range of climate effects?
B. What opportunities are offered by reduction of water demand and/or water reuse?
C. What are opportunities and setbacks of water supply by allocation and buffering?
D. What opportunities are offered by water technology and spatial planning?
E. How can we adapt to periods of water scarcity and water quality changes?
F. How effective are these strategies on different scales?

These questions reveal a strong need for research on practical solutions and adaptation strategies.

Aim

The aim of the proposed research is to develop robust, flexible and long-term solutions from a local to regional perspective which can contribute to successful strategies to bridge the growing mismatch between demand and supply of fresh water (quantity and salinity) in the changing Dutch Delta.

We can not cover the whole of the Netherlands and the proposed research will also not lead to complete strategies. Therefore the ambition or scope is to contribute significantly at least to strategy development for the three hotspotarea's involved in conjunction with other research and policy oriented programs (see also 3A2).

Central research questions

Our main research questions are derived from the questions as described above and apply within the above mentioned scope of the program.

1. What range of conditions should be taken into account to assess the severeness of an inadequate fresh water supply (evaporation, precipitation, river discharges, sea level rise and related salt water intrusion, international economic changes)
2. How will fresh-water availability within the coupled groundwater-surface water system change due to climate

change and how can the self-reliance of water users be increased?

3. To what extent can tolerance levels of different land uses be stretched? What opportunities for the reduction of the fresh water demand are possible?
4. What is the potential of water technology for providing solutions for regional self-sufficiency in the fresh water supply?
5. What approach should be used to build robust and flexible adaptation strategies, given the uncertainties in the long-term prediction of future climate change effects, and of other relevant socio-economic developments?
6. How can knowledge about specific adaptation measures, perspectives of different stakeholders, available approaches for tackling uncertainty, be integrated to build strategies for selected pilot areas.

Further elaboration of the research questions according to workpackages can be found under 2B2 and in appendices 1 and 2.

3A2 Programme outline and research approach

In the background document of the call for proposals the hotspot questions given above are further elaborated. The elaboration of the questions ask for quite complete and integrated (beta-gamma) analysis and solutions. In addition under the title of “service function” it is advised to seek cooperation with cross-cutting themes as Governance, decision-support tools and climate projections. The main questions are derived from a series of more specific, sometimes very localized hotspot questions. In this proposal we cannot cover all these angles simultaneously: being comprehensive, scientifically profound and tailored to the needs of all the hotspots

Therefore, we choose to focus on in-depth scientific research on promising local and regional solutions with impact on the national fresh water budget. The emphasis is on the agriculture and water supply sectors as well as nature. With this focus of ‘solutions at the source’ we connect best with the questions asked by the hotspots. Through up-scaling we can contribute to national policy oriented programs. In the period between pre-proposal and the writing of the full proposal the research questions have become more specific but there has been no reason for a different orientation or set up of the programme.

The Delta Programme, the elaboration of the national water plan with fresh water supply as a main theme, will be the main policy oriented programme in the forthcoming years. The research in our proposal will hence be carried out as much as possible in the context of this Delta Programme and will use the data and tools from their research, but will not address completely the national key issues involved in that programme directly. At the other hand it is expected that the outcomes of this KfC research programme will in turn be complementary to the national Delta programme.

Several disciplines will be combined in integrating cases. The work will be organized into research projects where involved stakeholders from the hotspots, PhD students, Postdocs and experts from research institutes will closely work together. Hence, the programme will not only have a high scientific and innovative profile, but will also result in practical solutions.

Break down of the programme

The programme is built around the research questions given above, which are directly addressed in 6 Work Packages (see figure below):

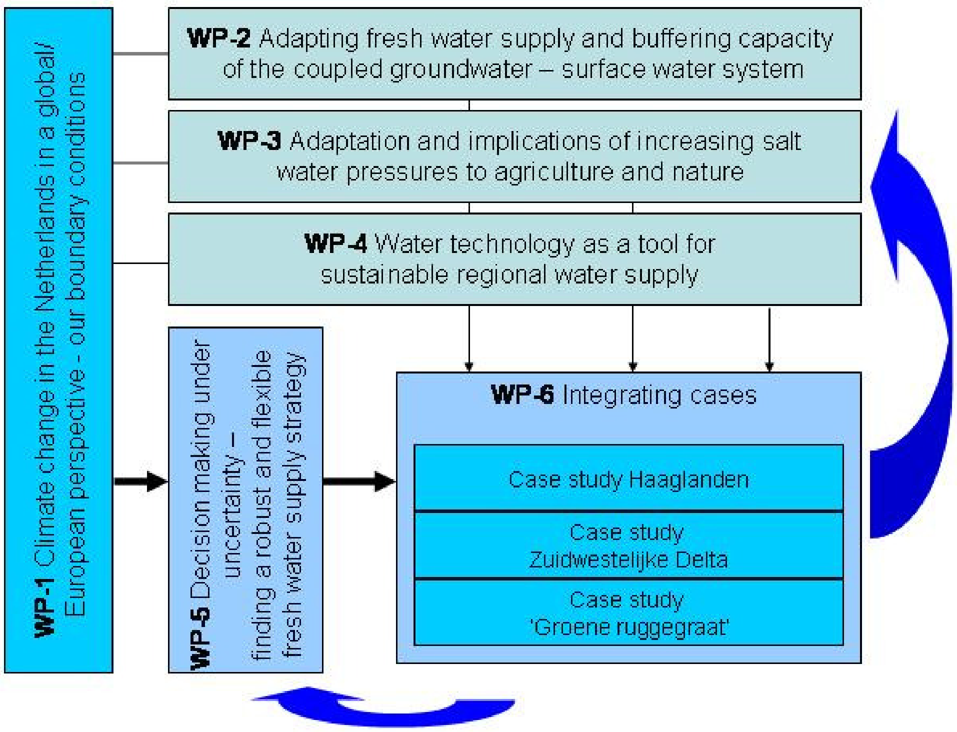

Figure 3.1 Outline of the programme.

In WP-2 to WP-4 the potential of different regional to local adaptation measures is investigated (WP-6). To be able to do this in the right current and future context, boundary conditions for climate, watermanagement and economics are elaborated in WP1. These boundary conditions will be associated with all sorts of uncertainties. In WP5 methodology and specific guidelines for decision making under these uncertainties in drought and salinisation risks are object of study. Finally in WP6, input from all other WP's e.g. potential of specific measures, specific boundary scenario's and guidelines will be used to build and test adaptation strategies for the case study areas.
WP-2 till WP-4 have a strong beta-orientation and are oriented at the core of this theme. WP-1, WP-5 and WP-6 include major gamma-components and have linkages with other themes, in particular theme 6, 7 and 8.
All WP's contribute to the pilots in WP6, but the pilots are at the same time also testcases for the measures or aproaches developed in the other WP's as indicated by the blue arrows in figure 3.1. Each WP has a particular study case (ranging from field experiments to inquiries) in one or more pilot areas. In this way knowledge and its applicattion is iteratively developed.

Main deliverables, outcome of the programme
The main outcome of the programme is expected to be that at the end there will be good insight in the potential of the investigated adaptation measures both for the regional cases and, through upscaling, national policy on a climate proof water supply and demand. For Hotspot parties a direct contribution to their regional adaptation strategies is made. So the main integration in this programme will be on the level of regional pilots. In cooperation with the Deltaprogramme we will try to put these regional solutions in perspective of national solutions (upscaling). Such an effort for synthesis will be made at the start of the programme as well as to the end.
In addition it is expected that there will be better understanding of what the most critical boundary conditions (e.g. return periods of droughts, low river discharges, tolerance levels, economic setting) are and how with the

uncertainties involved robust policy making is possible. Both aspects will be a valuable input to the national Delta programme.

3A3 Innovative aspects and scientific output

Integrated multiple scale approach
With this programme we aim at broadening scientific knowledge and creating innovative solutions to contribute to more robust and flexible strategies to balance fresh water supply and demand in a changing climate.
The innovative aspects on a general level are that we step down from the traditional top down national approach of guaranteeing the current service level by supply from the main water system and that we focus on bottom up local and regional measures.
Given the complex nature of the fresh water supply problem – e.g. high pressure on water resources, complex organization of the water system, uncertainties about future conditions – simple solutions are not available and an integrated approach should be applied instead. A coherent academic research programme that addresses all aspects of this problem specific for the Netherlands conditions, including adaptation strategies, has not been carried out yet. Different from most studies is that we look to the possible response of water management to climate change within the whole river basin and associated water availability for the Netherlands and that we consider the relative economic position of the agricultural sector in an international changing context.

Salinisation, drought and storage of fresh water
Up to now studies of the processes behind the dynamics and future behaviour of the fresh groundwater storage and the salinisation from groundwater to surface water are limited. Even fewer studies exist of the effects of measures (e.g. innovative drainage systems) to counteract negative consequences. (Preliminary) results of field monitoring and modelling studies suggest that local and regional solutions – buffering and dynamic control of the fresh water storage – could be feasible. It is, however, unknown which solution is most effective in which situation, to what extent and how these measures could be up-scaled to large areas. In this programme, all these aspects will be addressed.

Adaptation of nature and agriculture
There has been substantial research on salt- and drought tolerance levels of plant species. Some recent scenario studies have looked at potential impacts of climate change. The main scientific progress that will be made in this programme is that the tolerance will be better assessed taken into account a much more realistic variation of boundary conditions in time using multiple year long time series.

Water technology as a tool for sustainable regional water supply
In the Netherlands, there is little experience with water technologies to store surface water in aquifers for later use by ASR, to desalinate brackish groundwater (e.g. by reverse osmosis or Memstil) and to dispose of the membrane concentrate by deep well injection. Yet these techniques could become an option where fresh groundwater is becoming scarce due to both ongoing salinisation and increasing demands of high quality water for agriculture, industry and drinking water supply. In addition, various polluted waters (like sewage effluent, drain water from glasshouses and rain water) may become an alternative water source, when treated with modern techniques that outcompete traditional expensive systems that require too much space or energy. However, implementation of these techniques is currently hampered by lack of knowledge on (i) their performance under Dutch hydrogeochemical conditions and (ii) their heavily counting environmental impacts (especially the brine issue). Research is therefore needed to fill up these knowledge gaps, and to adapt and improve the techniques mentioned, in order to substantially contribute to local or regional fresh water supply.

Decision making and dealing with uncertainty
Compared to water safety issues little research has so far been carried out on decision making about drought and salinisation issues. Safety and drought are clearly different issues. Most focus in the Netherlands is on preventing an event (viz. the flood). Drought and salinisation issues on the other hand address a more continuous range of

conditions and a more complex set of interests. In addition, a wide set of variables may change in the long term (such as soil use patterns, developments in agriculture, etc.), requiring consideration of a broader set of uncertainties some of which may not easily be quantified (so-called deep uncertainties). Moreover, while traditional approaches to dealing with uncertainties have a primarily defensive character (how to prevent unwanted outcomes at acceptable costs), a more open approach will be followed in this programme, exploring opportunities that future developments may bring, and considering the application of (real) options in light of these.

3A4 Relevance of the research programme in an international context

The attention of the scientific world on the impacts of climate change on drought and fresh water supply (and the linked salinisation) has grown in recent years. This is not only due to events (such as the drought of 2003 in Europe) but also due to the realization that droughts and salinisation are strongly related to food security. The researchers involved in this theme are already participating in several international research programmes in this field. The proposed research is supporting these researchers in further developing their science and their positions in the international science community. Although the main focus of the theme is on the drought and fresh water supply issues as existing in the Netherlands, in general the science and methodology involved is applicable in other parts of the world, in particular deltas. To give a few examples:

- Both the hydrological and economic situation around us will determine how hard we as the Netherlands will be hit when drought strikes or what kind of opportunities will emerge. The research on boundary conditions will be carried out in cooperation with European partners, in particular those involved in the Rhine and Meuse basins. This will give valuable insights for all parties.
- The KfC research will devlop strong ties with the Delta Alliance, a netwerk of Deltas with often similar problems (Francisco Bay, Vietnam, Indonesia and the Netherlands). Topics, like salinisation, drought and solt tolerance of crops, water technology, policy making under uncertainty will be applicable and can be shared within the network.
- Recognizing deep uncertainties and explicitly and methodically dealing with them in long-term planning and policy making is a relatively recently developed research field meeting with increasing international interest. The proposed work in WP-5 will help to strengthen the leading position of the Netherlands, in particular with respect to fresh water supply. We know of only one earlier application of a broad uncertainty analysis approach to a water supply problem world-wide, so there is much to be added and developed.

3A5 International cooperation

In preparing this proposal contacts have been made with international experts and institutes whose specific scientific knowledge is expected to benefit the quality of the proposed research. Their input will either be by involving them in the projects as actual research partner or by asking them to provide an advising or supervising role in a project, a Work Package or the full programme. For the full programme a Scientific Advisory Board will be established who will meet twice to discuss the approach and progress of the projects. The following cooperation is foreseen:

Partners that will actually be involved in the project as **research partners**:

- Bundesanstalt für Gewässerkunde (dr. Thomas Maurer) - Germany, prominent partner of the KLIWAS project and the key applied research institute in this field in Germany, in particular for project 1.2
- British Geological Survey (Dr. Richard Ogilvy) – United Kingdom. Dr. Ogilvy´s role is to advice and supervise research in the field of applied geophysics for near-surface environmental, engineering and hydrogeological problems, for projects 2.1 and 2.2, among others for implementing an automated system for the long-term monitoring of vulnerable coastal aquifers and surface water systems. He is the developer of the Automated time-Lapse Electrical Resistivity Tomography (ALERT) system with EU FP6 funding (GOCE-CT-2004-505329). The ALERT technology (viz. getting geo-electric property changes) will directly be related to hydrogeochemical processes in the water system, particularly to salinisation in coupled groundwater - surface water systems. Dr. Ogilvy will be involved in the work of WP-2.
- University of Bologna (prof. Marco Antonellini) – Italy. Marco's role is incorporate his ongoing research in groundwater - surface water interactions in the Po Delta with our research findings in our Dutch Delta, for WP-2.

- Dr. David Pyne – United States, world renowned expert on ASR, author of the only existing book on ASR applications, for project 8.
- EPFL (Ecole Polytechnique Federal Laussane), Hydrology and Water Resources (prof. Andrea Rinaldo), Transport phenomena in the hydrological, ecohydrology etc, providing guidance and inspiration to several PhD students involved in the theme, in particular of WP-1, WP-2 and WP-3.
- INGREF (Tunisia), Centre National de Recherche en Genie Rural, Eaux et Forets (dr. Fethi Bouksila). Will give access to conduct experiments in Tunisia on the tolerance of different crops to salt as experimental fields are available on a fresh-salt gradient through Tunisia, in particular relevant for projects 3.1 and 3.2.

Experts / top scientist for advice and supervision (**Science Advisory Board**)

- Dr. Christian Langevin, U.S. Geological Survey. Dr. Langevin is an expert of research on the interaction between groundwater - surface water systems. especially in the Florida Area, a low-lying area like to the Dutch Delta.
- Prof. Richard Harding, Head of the Climate Section at CEH Wallingford. This group researches into the improvement of the representation of the land surface hydrology in global models. Deputy Director of CLASSIC EO Centre of Excellence, Partner in more than 15 EU projects (FP3-FP6).
- Prof. Dr. Robert Lempert, senior scientist at RAND corporation, specialist on long-term policy analysis; risk and uncertainty management; strategy under uncertainty.

In addition there two international workshops will be held (see section 4C)

3A6 Most important references (max. 15)

A6 is not to be included in the total word count of part 3A.

We consider the following references in particular relevant as base documents for the theme on fresh water supply

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3B. Interdisciplinarity (max. 500 words)

The programme intends to result in a methodology towards a climate proof fresh water supply, through robust and flexible solutions. This requires an interdisciplinary approach, as a wide range of issues need to be looked at, and a number of stakeholders with very different agenda's need to be involved in the process.

The consortium therefore includes a number of renowned organizations, reflecting the importance of cross-Institute and inter-disciplinary collaboration for meeting the complex tasks set by the project, but thereby also using the resources more efficiently. By including universities, research institutes and the private sector the project is approached both in a fundamental and applied manner.

The involved research groups cover a wide range of disciplines. These disciplines include:
Natural sciences (including physical processes, monitoring, modeling) and technology: WP-1 (partly) and WP-2, WP-3 (which includes socio-economic issues) and WP-4; Socio-economic and policy sciences: WP-1 (partly) and WP-5-6; Applied research (applying research into practical solutions): WP-6

The expertise of the research groups is complementary and broad enough to ensure that all disciplines are represented. Although research is the key focus, the project will eventually result in insights that help the stakeholders to develop a methodology towards a climate proof water management system. Evidently, by including a number of case studies, the outcome of the different work packages can be integrated. It must be stressed that the researchers from the different research projects will be actively involved in the case studies. These cases will enrich our own developed knowledge but also offers very relevant test cases to the other themes.

In addition tot the expertise available within the consortium, the cooperation will be actively sought with the cross-cutting themes 6,7, 8 to have available knowledge on: latest regionalized insights in drought scenario's and social economic scenario's, on economic valuation of adaptation options and on the organization of stakeholder participation.

3C. Coherence between and synthesis of outcomes from the individual work packages (max. 500 words)

In this section, we will explicitly point out the connections between the individual WPs.

The proposal can be grouped into three disciplines (see Figure 3.1 in Section 3A2), viz.
1. Natural sciences (including physical processes, monitoring, modeling) and technology: WP-1 (partly) and WP-2, WP-3 and WP-4,
2. Socio-economic and policy sciences: WP-1 (partly), WP-5 and WP-6,
3. Applied research (applying research into practical solutions): WP-6,

Activities within WP-6, The Integrating Cases, ensures the coherence of the different WPs spanning these disciplines. For these Integrated Cases, viz. Haaglanden, Coastal Fen Meadows and South-western Delta, input from the WP-1, WP-2, WP-3 and WP-4 is vital to a successful implementation of hotspot adaptation strategies. Moreover, to be able to make the step from single measures to long term strategies, given the uncertainties involved, concepts and guidelines to design and implement robust and flexible strategies will be developed for the cases in WP-5. Activities within the more fundamental research of WP-2, WP-3 and WP-4, such as field measurements, water system analysis, modelling, interview surveys, are carried out by PhD students and Post-docs in the physical component of the three Cases, so that WP-6 can make direct use of their preliminary results. An important role for the WP coordinator of WP-6 (together with the overall consortium leader) is to link the Cases (addressing the specific questions and issues of the hotspots) with the various research activities carried out in the other WPs (see Section 6E 'Management of the research programme'). Vice versa the coordinators of the "technical" WP's 1-4 should ensure that the research carried out under their guidance is tuned to the needs of the cases as far as possible.

The consortium will organize scientific meetings for the whole consortium (including PhD students and Post-docs) at least twice a year, where all projects will be presented to each other and thoroughly discussed by all team members. For the PhD students in particular a summer school will be organized. Integration of the results of the WPs is also taking place during the discussions and knowledge exchanges at the (international) workshops (see Appendix 8 'Time planning').

In addition, specific WPs have strong interrelations with each other. These relations are identified below:

- WP-1 and WP-5: results on the variety of possible future boundary conditions for the Netherlands (WP1) will be used in project 5.1 ('Adaptation under uncertainty: resilience as a strategy for climate proofing fresh water';
- WP-2 and WP-3: changes in the fresh water volumes in brackish-saline environments or the salinity of surface water (both projects of WP-2) are closely linked to increasing salt water pressures to agriculture and nature (WP-3), e.g. via the quantification of present and future salt damage to crops;
- WP-2 (project 2.2) and WP-4 (project 4.1) are both focused on medium sized fresh water lenses in sandy creeks in brackish-saline environments: WP-2 on the quantification of the effects of changing boundary conditions under different hydrogeological conditions, and WP-4 on the performance of storage techniques in terms of water quality, storage capacity and recovery efficiency;
- WP-4 and WP-6: technological options for increasing self sufficiency of water supply developed in WP-4 will be tested in WP-6;
- WP-5 and WP-6: the case-based more in-depth uncertainty analyses performed in WP-5 will directly feed into WP-6.

The mutual cooperation between the researchers of the WPs will be encouraged and therefore specialists of each consortium partner will have a task in each WP, wherever deemed relevant. In addition 10% of all scientific input (PhD students and Post docs, equivalent to 285 k€) in WP-1 to WP-5 is directed to WP-6. Each PhD student will be active in two cases, and if applicable, they will jointly work on the same problem.

All the abovementioned actions will ensure that outcomes of one WP are directly available to other WPs and that adjustments to the research directions can be made in time to serve the overall goals of the programme and the stakeholders involved.

3D. (Expected) cooperation and coherence with other research themes (max. 500 words)

At various research fields potentials for cooperation with other themes have been identified. Discussion with the other themes have in some cases resulted in concrete agreements on cooperation (and are included in this proposal), in other cases it is still to be worked out on how such cooperation will take place.

Concrete agreements on cooperation have been reached with:

- Theme 1 (Water safety): joint PhD research on robustness analysis methods. Each theme has included half a PhD where we jointly carry out the development of the conceptual framework. The framework will be applied on flooding (theme 1) and on drought (theme 2).
- Theme 3 (Rural areas): their PhD-project “The future groundwater recharge: evapotranspiration response of vegetation to climate change” will be carried out in close co-operation with our PhD projects 2.1, 2.2, 3.1 and 3.3. Within theme 3, maps of ecosystem functioning will be made which rely amongst others on data on the salinity of surface waters (project 2.2). This theme will also investigate the potential adaptation strategies of farmers, which are determined partly by the availability of fresh water. Within the case ‘Groene Ruggengraat’ (project 6.1) interviews with farmers and NGO’s as a basis for agent based modeling will be done jointly with theme 3.
- Theme 6 (Climate projections): very strong linkage between several projects of WP-3 of theme 6 and various projects of our theme. In particular the following cooperation agreements have been made:
  - their project 3.1 and our project 1.2 where theme 5 will take care of the climatology while we will take care of the water management aspects. The hydrology we will do jointly.
  - cooperation between the PhD in their project 3.4 (coupling of hydrological and land use models) and our project 2.2 (hydrological modelling of groundwater-surface water interaction)
  - their project 6.7 (uncertainties in adaptation) and our WP-5 (Decision making under uncertainty)
  - the use of our integrated cases in the research of their projects 3.2 (coupling of climate and agronomic models) and 3.3 (case coupling of climate and ecosystems models)
- Theme 7 (Governance): close cooperation between our WP-5 (Decision making under uncertainty) and their WP-4 (Dealing with controversies) and their WP-5 (normative principles: legitimacy effectiveness and resilience). Theme 7 will address the same issues of resilience, adaptive capacity, etc., but they address the governance or institutional system, while the uncertainty-oriented research in our theme 2 addresses the socio-ecological system and the policies applied to that system.

Less concrete but still promising are the cooperation potential with the following themes. Contacts have been established but the mode of cooperation still have to be worked out in detail.

- Theme 5 (Infrastructure). In this theme the effects of exposure of concrete structures to saline groundwater will be investigated in WP-2 (Climate proofness of physical infrastructure), which potentially links to the research on salinisation in our WP-2.
- Theme 6 (Climate projections). Besides above specific cooperation we anticipate that theme 6 will provide the meteorological (rainfall, evaporation, etc.) boundary conditions under climate change for our cases studies in WP-6.
- Theme 8 (Tools) addresses decision making under uncertainty from a primarily economic, social cost-benefit analysis; they will also elaborate economic approaches to investment decisions under (long-term) uncertainty which has strong ties with our WP-1 and WP-5.

Another form of synergy will be generated by cooperation on the three cases of our WP-6. The following cooperation possibilities are identified and partly already agreed upon with the other themes:

- Theme 3 (Rural areas) in particular in our integrated cases ‘Groene Ruggengraat’ and ‘Zuidwestelijke Delta’.
- Theme 5 (Climate projections), in their WP-3, in particular in our integrated case ‘Groene Ruggengraat’
- Theme 7 (Governance) in our integrated cases ‘Haaglanden’ (project 2.2: Realizing climate robust multifunctional land use through system synchronization) and ‘Zuidwestelijke Delta’ (project 2.3: The multilevel governance of climate adaptation)

3E. Connection to finalized and current projects in KfC and other research programmes (max. 750 words)

Given the wide scope of this proposal there are many connections with KfC and other research programs. Below we highlight only a few, categorized by work package.

- **WP-1:** The socio-economic component of this WP has connections with (among others) the PROMO project (Perceptions and Risk Communication in Flood Risk Situations, BSIK Project Leven met Water) and ENSURE (Enhancing resilience of communities and territories facing natural and na-tech hazards, EU FP7 project). The hydrological/water management part is a direct continuation of various research projects that are carried out by KNMI, RWS and Deltares. In addition a link will be made with related research programs in Germany (KLIWAS), France and Belgium.
- **WP-2:** Strong links with ongoing research on fresh-salt water relations within various projects and programs such as the "Leven met Water" BSIK programme "*Leven met Zout Water*" project; the project "*Salinisation and freshening of phreatic groundwater in the Province of Zeeland*"; the Interreg projects Cliwat (on determining the effects of climate change on groundwater systems and through this on surface water and water supply, www.cliwat.eu), Climate Proof Areas and Scaldwin; the KfC project "*Demand and supply of fresh water in the South-western part of the Netherlands : an exploratory investigation* (viz. *Meta-studie Zuidwestelijke Delta*)"; the Waterhouderij in the Province of Zeeland (WINN project); and the EU Water supply and sanitation Technology Platform Pilot Programme Mitigation of Water Stress in Coastal Zones.
- **WP-3*:*** Strong connections to the COST network of Prof. T. Flowers/Prof. J. Rozema). The ongoing cooperation with Ben Gal, Russo, and co-workers (Gilat Res. Centre, IL) is particularly focused to combining the physical/hydrological aspects of agriculture under saline conditions with micro- and macro-economic theory and pricing of water as a management tool. This aspect is brought into the research of project 3-1 in view of the reviews. Furthermore, project 3.1 & 3.3 are closely linked with the cooperation projects of Wageningen University and Deltares, and with Vervoort (Un. Sydney, AU), and Porporato (EPFL, CH & Duke Un., USA).
- **WP-4:** Strong connections to the EU-TECHNEAU network, the EU WSSTP Task Force MAR, and cooperation with Henning Prommer (CSIRO, AU) and David Pyne (ASR Systems, USA). Salinization of fresh water resources is a major research topic in the joint research programme of the Dutch drinking water companies. KWR carries out this research programme. Considering salinization, the research focuses on the following themes: a) dynamics of salinization of intake points and prevention; b) optimization of storage concepts, such as ASR; c) optimization of desalination techniques and minimization of the environmental consequences (e.g. brine injection).
- **WP-5:** The researchers involved in this work package are already involved in various climate related research project, both national as well as international. Through the network of the researchers involved there will be a direct relation with related work at the Copernicus Institute for Sustainable Development and Innovation (Utrecht University) and the research projects sponsored by the Next Generation Infrastructures Foundation (sub-program: flexible infrastructures)
- **WP-6:** The cases for The case study proposed within the hotspot Zuidwestelijke delta will be a scientific extension of the KfC project "*Demand and supply of fresh water in the South-western part of the Netherlands : an exploratory investigation* (viz. *Meta-studie Zuidwestelijke Delta*)" and the KfC project " Negotiating uncertainties: *defining climate proofing and assessing associated uncertainties in the Southwest Delta Region of the Netherlands"* . The case 'Haaglanden' will be connected to various research projects and policy studies in the region and take into account the results of previous KfC projects on the topic of self-sufficiency. The case 'Groene Ruggengraat' will continue the work as done in the studies "*Waarheen met het Veen*" and has a strong connection with the "*Groene Hart study*".

In addition to above we will use the extensive scientific networks of our lead researchers. This include, among others: IWA specialist group on climate change (KWR is secretariat of this group, the Delta-Alliance (Deltares and WUR are leading parties in this international network of Deltas under climate change) and the involvement of WUR, Deltares, KWR etc. in various FP6 and FP7 EU research projects. As mentioned before the research is set up to contribute to and to avoid overlap with the Delta programme. This can be well managed since Deltares and Alterra are also active in the study on fresh water supply within the Delta programme.

4 SOCIETAL ASPECTS

4A. Relevance of the research programme for national and regional adaptation policies (max. 1000 words)

This KfC research programme explores the extent to which the Dutch long-term strategy for fresh water resources management is adequate, sustainable and how it can be improved. The basic societal relevant question that have to be answered are:

- To what extent of climatic changes can we sustain a profitable and ecological sound land use, within the low lying areas of the Netherlands threatened by increasing salinisation, droughts and soil subsidence? and subsequently:
- What adaptation actions should be taken, given the projected climate and societal changes and associated uncertainties?

This KfC research programme provides knowledge and insight on the performance of different strategies in order to support main political choices on a national and regional level like: "should there be a shift to more regional self support of fresh water supply?", and if so, "can we reach this best by improving water management, using technological solutions or by changing land use?" The results will in this way support the preparation of robust and flexible investment strategies on national and regional level to enhance the freshwater availability.

The main policy framework in the coming years is the Delta programme that has two main objectives: how to reach a climate proof water safety and how to reach a climate proof fresh water supply in the Netherlands. The ongoing applied research project on fresh water supply within this Delta programme (in Dutch project 'Verkenning Zoetwatervoorziening Nederland') is carried out by Rijkswaterstaat (Waterdienst) and Deltares, using large models that assess the effects of climate and adaptation options on national and regional scale. Complementary to this applied research project this KfC research programme adds in-depth, innovative and exploratory research on promising adaptation strategies starting from the local and regional scale. It is expected to yield new insights which cannot be foreseen beforehand. It is on this point that our proposal intends to make a difference in order to provide additional relevance for regional and local adaptation policies.

Many efforts are currently undertaken to embed adaptation strategies into regional development projects, the current corner stone of Dutch spatial planning. This gives the opportunity for tailor-made solutions for optimizing freshwater availability. However, this regional approach has some drawbacks too. For example, the transfer of burdens from one region to another. Therefore in this KfC research programme the question is always ask how a regional strategy relates to neighbouring regional and national approaches. This is also expressed in the three integrated cases (WP-6) provided by the programme. There is one supra-regional case ('Groene Ruggengraat') which considers and counterweights all stakes, policies, regarding optimizing fresh water supply and demand within an area covering parts of three provinces and there are two more regional cases ('Haaglanden', 'Zuidwestelijke Delta') in which a regional strategy aimed at more self support is explored opposed to strategies that rely more on external supply of fresh water.

The three cases provide direct relevance for regional adaptation policies. Partly these policies are directly connected to the regional projects within the Delta programme i.e. South-West Delta (case 'Zuidwestelijke Delta') and, Rijnmond and Drechtsteden (cases 'Haaglanden' and 'Groene Ruggengraat'). Further input will be generated to support water management plans from the provinces of Zuid-Holland, Utrecht, Noord-Holland and Zeeland and relevant water boards (i.e. Beleidsvorming Droogte Groene Hart/Zuidvleugel Acuut, Ruimtelijke Consequenties van het droge klimaatscenario in 2050, Droogtebestrijding Groene Hart – Geen spijt maatregelen verandering zoetwatervraag).

This KfC research programme does not start from scratch. New concepts for climate proof freshwater resources management have been introduced in national policy programmes such as the National Water Plan (NWP, "meebewegen als het kan, weerstand bieden als het moet") and the ARK programme (a climate adaptation policy programme focusing on spatial planning). On-going and recent research (e.g. "Meta-studie Zuidwestelijke Delta", "Waarheen met het Veen", "Droogtestudie Nederland", "Klimaatbestendigheid NL Waterland", "Leven met Zout Water") provide (applied) science to underpin climate proof fresh water management on different scales on which this programme builds upon. Several consortium partners (in particular Deltares, Alterra and KWR) are and were intensively involved in these programmes, which should ensure that the consortium can identify those research questions, which are not yet addressed in on-going research.

4B. Involvement of stakeholders (max. 750 words)

Stakeholder involvement in the initial process of formulation of this proposal
In the initial phase the research agenda for this project was formulated in dialogue with involved scientists, provinces(Zeeland, Zuid-Holland, Noord-Holland, Utrecht), water boards (Schieland en de Krimpenerwaard, Delfland, Rijnland, Brabantse Delta) and other stakeholders (Rijkswaterstaat, LNV and ZLTO).,

Financing of the research by stakeholders
Many project activities will be co-financed by regional and national policy institutions as well as private institutions (Stichting Natuurmonumenten, STOWA), up to approximately 15-20% contribution in the total research costs. In addition 10-15% of the total budget include synchronizing on-going R&D activities of stakeholders (ZLTO, Brabantse Delta) with our proposed research.

WP-6 Collaboration with on-going activities of stakeholders
Tuning of planned research activities with on-going stakeholder activities in the field of fresh water resources management is a responsibility for WP-6. Stakeholder meetings in WP6 will be tuned with the agenda of the Delta programme, in particular sub-programme 'Freshwater Resources' and sub-programme 'Southwest Delta' with the relevant project leaders of V&W, LNV and programme Office Southwest Delta.

The case climate proof, and sustainable water use in the south western Dutch Delta area will focus on (1) water storage at the local scale and (2) water management at the regional scale. For the first component there will be a parallel 'in practice' project executed by the local agricultural organisation (ZLTO) in which researchers of this KfC research programme will part time participate For the second component there will be a parallel with the planned pilot project in the Zuidwestelijke Delta executed under the national Delta program.

In the case 'Haaglanden' a joint learning environment ('leertafel') is organized in which stakeholders and researchers work together on more practical questions. These activities will be done in co-operation with Water Framework Haaglanden. This is a cooperation between the water authority, Delfland Water Board, the Province of South-Holland and the City Region of Haaglanden with its nine municipalities.

The case 'Groene Ruggengraat' geographically lies within the "Groene Hart". Recently a study issued by all provinces and waterboards related to the "Groene Hart" has started in which the water-demand and no-regret measures to reduce this demand in a number of pilot areas is assessed. From this assessment a number of questions will come forward requiring more in depth research from our KfC research programme. In addition we aim to tune stakeholder interactions that are being planned in the context of 'Uitvoeringsprogramma FES Westelijke veenweiden', 'Uitvoeringsprogramma Randstad 2040: inrichting van een Groene Ruggengraat' and the KfC programme.This tuning will be done with programme office Groene Hart (www.groene-hart.nl), Laag-Holland (www.laagholland.nl) and project Hollandsche Ijssel (www.schonermooier.nl).

WP-6 Process management of stakeholder involvement
During the execution of the research programme the interaction between the stakeholders and research activities within the other work packages will in particular be organized through WP-6 in the three integrating cases: a. case 'Haaglanden', viz. "Improving regional self support of Greenhousing and Industry in the Westland area"; b. case 'Zuidwestelijke Delta', viz. "climate proof, and sustainable water use in the southwest Dutch Delta area" and c. case 'Groene Ruggengraat', viz. "combined adaptation for agriculture and nature in the 'Groene Ruggengraat'.

For each case study a working group and steering group (waterboards, provinces) will be created consisting of relevant project leaders of WP1-5, stakeholders and key persons in relevant science-policy interfaces. This working group is responsible for tuning stakeholder interactions (workshops, interviews, surveys) between the involved researchers and stakeholders. In addition the 3 chairs of the working groups meet frequently to tune proposed stakeholder interactions within and outside this research programme. More specifically, we shall organise meetings and workshops, where the research team and the stakeholders can discuss the objectives, the approach, the specification of research questions, etc., as well as any preliminary results and their applicability for each case study. In addition researchers will be working partly on location at the office of relevant stakeholders (province, water board).

Approach in the stakeholder workshops within the case studies
In the 3 working groups of the cases joint fact-finding (Eerman and Stinson, 1999) between involved scientists and practitioners and policy makers will be stimulated. In short, employing joint fact-finding means addressing a factual dispute by forming a single fact-finding team comprised of experts and decision-makers representing both sides of the dispute. The factual dispute(s) to be discussed in the workshops is built upon the main objective of the research proposal, the aim to find solutions for the growing mismatch between freshwater supply and demand in the short- (2015) and long term (2050/2100). Amongst others, disputes to be discussed are:

- The level of (dis)agreement about the sense of urgency to tackle this issue (problem framing)
- Water demand management versus water supply management (costs and benefits)
- The (perceived) level of 'no-regret' of proposed strategies/measures on case study level
- Resilience approach versus Robustness approach (in co-operation with WP-5)

Lessons learned in the field of 'action based research' will be embedded into our approach in case study 'Haaglanden' in collaboration with KfC theme 7 (Erasmus University, Arwin van Buuren).

Objectives en approaches of planned surveys and interviews
In collaboration with WP1 (, KfC *project " Negotiating uncertainties*: defining climate proofing and assessing associated uncertainties in the Southwest Delta Region of the Netherlands" and KfC theme 3 (Rural Areas) consultation of stakeholders (interviews, internet surveys) in fresh water resources management are planned in collaboration with TNS-NIPO and ZLTO. The general objective is to assess how resilient individual agricultural entrepreneurs are regarding economic drought and salinity damage and how they deal with uncertainties. The results are used for Agent-Based modelling (KfC theme 2), Exploratory Modeling/Analysis (WP-5) and guidelines for dealing with uncertainties in negotiating processes (KfC project Negotiating Uncertainties in collaboration with WP5).

Stakeholder involvement on programme level
For the project as a whole a steering group will be installed that will represent the national, regional and local water managers and policy makers from the hotspots. The steering group will advise the programme management on the link between the actual issues they are facing with respect to guaranteeing freshwater availability and the research that will be carried out in this theme 2.

It is further expected that for specific projects separate guiding groups will be organized within the framework of the steering group.

4C. Knowledge transfer and valorisation (max. 750 words)

From research to practice and policy

By the process of joint fact finding and tailoring of adaptation strategies in cases described under 4B an important part of the valorisation of the results is reached.

By means of overlap in personnel and by participation in mutual workshops there will be a regular exchange of information and results between the research programme and the Delta programme project fresh water supply. This programme intends to organize a joint 'fact-finding' workshop together with stakeholders and 'investors' to ascertain that there is consensus regarding the primary questions that have to be addressed and to discuss the relationship between those primary questions and the disciplinary and interdisciplinary scientific issues that are formulated in this proposal. This workshop is organized in the first months of the program 'Climate proof fresh water supply'.

From research to other stakeholders

A user community will be established around the project. Once a year a workshop will be held to communicate latest results and to get feed back from stakeholders outside the areas directly under study. In these workshops also consultants involved in parallel projects are invited to exchange experiences. Twice a year the user community will be informed about latest results, relevant developments etc., by means of a newsletter.

International hotspots

In the framework of the Delta Alliance and together with other research themes we will participate in activities (research proposal international hotspots, capacity building) to promote and transfer the Dutch Knowledge to other low lying deltas. It is very likely that other geographic regions, such as the Mediterranean area or the Indian or Chinese coasts, but also the international hotspots, will be subject to similar or even higher impact effects of climate change on society. This offers several opportunities to broaden the scientific perspective of this program and to attain synergy with international research calls, such as from EU, FAO, and other international frameworks such as UNESCO. In particular, the 'Young Professional Network' provides opportunities from all sides for synergistic cooperation. This may be shaped in the form of summer schools, joint integrative papers, (hand)books, and protocols, and other network activities, as well as new joint proposals.

From research to research

There are 7 PhD projects in the research proposal. Each of these project will have to generate about one scientific reviewed paper each year. The role of our foreign research partners is not only to safeguard scientific excellence of research but also vice versa the results obtained in the project are shared with them. Researchers involved will visit international conferences. On the coming KfC conference "Deltas in Times of Climate change" we intent to organise a workshop on the issue of fresh water supply. Our foreign partners in the project will a.o. be asked to contribute. Near the end of the programme a second international workshop is foreseen.

In order to enhance interdisciplinary skills of the seven PhD researchers a summer-school will be arranged in co-operation with the involved international partners. This summer school has three objectives (1) exchange knowledge across the involved disciplines regarding climate proofing fresh water supply and demand, (2) improve academic skills to publish interdisciplinary papers and (3) to cope with scientific uncertainties and negotiation processes between science and policy about climate proofing fresh water supply and demand. We hope that the summer school will result in a multi-author paper either for a scientific public and/or a broader audience.

Other

The project is assigned a KfC Website on which a popular description of the project, an agenda of activities, relevant publications and the aforementioned newsletter will be available.

The results of this project can be disseminated internationally through various networks in which the consortium partners are involved. For example, (KWR) is secretary to the IWA Specialist group on Climate Change. IWA is the leading global organization of water professionals. Deltares is member of the UNESCO-GRAPHIC group (Groundwater Resources Assessment under the Pressures of Humanity and Climate Changes), is partner in EU several Interreg IVB North Sea Region programmes and Wageningen UR is involved in a cluster of EU funded projects dealing with global change, climate adaptation and water cycle (ADAM, WATCH, SCENES, AQUASTRESS**,** NEWATER, SoilCAM, Carbo-North) and the co-operative programme on water and climate.

5 WORK PACKAGES AND PROJECTS

work packages	projects
1. Climate change in the Netherlands in a global and European perspective – our boundary conditions	1.1 Prospects of the Netherlands under climate change in a global and European perspective 1.2 Impacts of upstream climate change induced developments for the Netherlands
2. Adapting fresh water supply and buffering capacity of the coupled groundwater-surface water system	2.1 Development of a quantitative framework to optimize adaptation strategies to droughts and salinization in groundwater–surface water systems under climate change 2.2 Increasing the robustness and flexibility of fresh water lenses in saline seepage regions under climate stress
3. Preserving and adapting functions to limited fresh water supply	3.1 Developing climate proof Dutch Salt Tolerance Response Functions for crops 3.2 Adaptation to dry and saline conditions by crop cultivation exploiting brackish water while saving fresh water 3.3 Predicting effects of changing salinity on inland natural systems on the Dutch coastal plain
4. Water technology as a tool for self-sufficient regional water supply	4.1 Water storage for self-sufficient regional water supply 4.2 Water technology for self-sufficient regional water supply
5. Decision making under uncertainty – finding a robust and flexible fresh water supply strategy	5.1 Adaptation under uncertainty; resilience as a strategy for climate proofing fresh-water dependent networks of protected areas (‘Groene Ruggengraat’) 5.2 Robustness analysis methods to support flood and drought risk management policy making 5.3 Toward robust decision making for fresh water supply
6. Applying knowledge in integrating case studies	6.1 Case study ‘Groene Ruggengraat’ - climate proof water and land use in coastal meadows of the Netherlands 6.2 Case study ‘Haaglanden’ – towards a more robust, self-sufficient fresh water supply of the Haaglanden region 6.3 Case study ‘Zuidwestelijke Delta’ – climate proof and sustainable water use in Dutch Delta area

6 FINANCIAL ASPECTS, PLANNING AND MANAGEMENT

6A. Total budget for the research programme and its distribution across the work packages, including justification (max. 750 words)

An overview of the provisional budget of the theme and a breakdown over work packages en partners are given in Appendix 6. The total budget for the theme is set at 4.975 k€ and consists of 2.500 k€ KfC-subsidy, an expected 1.116 k€ co-financing and an own contribution of the partners of 1.359 k€.. The budget is provisional as no firm commitments for the full co-financing could be arranged yet at the time of submission of this full proposal. Depending on the actual co-financing we might need to adjust our programme somewhat.

The formulation of the activities (the research) and consequently the distribution of the budget over the work packages are strongly based on the research questions of the hotspots. This has resulted, among others, in an strong emphasis on the applicability of the research in the three cases (WP-6), stronger than was planned for in our pre-proposal. The interaction with the stakeholders about the content of the research during the formulation of the proposal was good. At the other hand the results of our communication with the same stakeholders about co-financing were very disappointing. At the date of submission of this proposal only vague indications of possible contributions were given. As the execution of the activities will depend on the availability of co-financing this might mean that we might be forced to shift some budget from those activities that lack co-financing to activities that do get support.

Further explanation and motivation

- The more academic research (PhD and post-doc) activities are carried out by the university partners (Wageningen, Twente and VU University Amsterdam, TU Delft and University Utrecht). The role of the knowledge institutes (Deltares, Alterra, KWR and TNO) in this PhD research will be a more supporting one, guiding the academic research or providing specific expertise needed for the integrated application. At the academic level there are 7,5 PhD students (one PhD student is shared with theme 1) and 3 Postdoc-researchers in the programme, covering about 68% of the total budget. The PhD part only covers 50%.
- The more applied oriented research activities will be carried out by knowledge institutes of the Consortium. It is noted that there is no clear cut boundary between the knowledge institutes and the universities as several (lead) researchers of the knowledge institutes have also positions at the universities. Some of them will act as promoter for the PhD students.
- The costs for one PhD student are based on 300 k€ for the PhD candidate, about 60 k€ for supervision and an estimate for research costs (surveys, field measurements, etc.). The 60 k€ supervision costs is divided among the university and the institutes depending on the specific conditions under which the PhD candidate will carry out his/her research.
- The costs for a Post-doc input at University level is based on 100 k€ per year, excluding additional costs.
- The costs for researchers at the non-university institutes are based on the normal commercial fees of these institutes.
- The costs for project management are given in Section 6E2. Based on experience in similar research projects involving many universities and institutes it is stressed that the effort needed for coordination and management should not be underestimated.
- As mentioned in Section 3A5 we propose to install an international scientific advisory board that advises us on the approach of our research and will comment on our progress and (preliminary results). The cost involved include travel, accommodation and where necessary a modest fee.
- In several projects we intend to develop scientific cooperation with renown international universities and institutes working in the same fields. We anticipate that most of the research carried out in cooperation will be funded by own sources but for those cases where that is not possible we have included a budget to cover the costs involved in the 'material' costs of the project involved.
- Dissemination activities are described in Section 4C. Cost involved are organizational costs for workshops, seminars, symposia, the summer school, web-site as well as for publications

DISCLAIMER: As mentioned above. At the time of submitting this proposal we have not received firm commitments for the required 1.116 k€ co-financing (see Appendix 7). If we will not be able to arrange for this full co-financing we will have to adjust our research programme. Moreover, it appears that most co-financing will be made available for specific projects only. This all means that for certain projects we will have to scale down our activities. It might also mean that we will be forced to skip some projects completely. This might in particular be the case for the PhD projects which cannot be 'scaled down'. This will effect especially WP-2 and WP-3. Some PhD projects might get additional support by increasing the own contribution.

6B. Sources

The 'Sources' of the budget are given in the Excel document 'Appendix 6 Financial aspects'.

6C. Adjacent projects

Nearly all of the proposed research activities in this theme have direct links with other climate related projects. Some of these adjacent projects are application oriented (e.g. aiming to support actual decision making), others are more fundamental in nature (e.g. continuation of on-going NWO research). The following list is a tentative list of such adjacent projects in which the consortium partners are actively involved:

- Reconnaissance study Freshwater supply (Zoetwaterverkenningen – Deltaprogramme) – Deltares, Alterra
- Study on the impacts of climate change in the Northern parts of the Netherlands – Acacia Water
- Adaptation to climate change at the local scale – VUA-IVM, Acacia Water, BothEnds
- Climate changes Spatial Planning Programme (CcSP), project A1 (Ecohydrology)
- Salinisation and freshening of phreatic groundwater in the Province of Zeeland – Deltares
- Interreg IVB North Sea Region programme Cliwat, www.cliwat.eu – Deltares
- Interreg IVB North Sea Region programme Climate Proof Areas – Deltares
- De Waterhouderij (Rijkswaterstaat, WINN) – Deltares
- Regional scale optimization of land and water resources- HEC Pakistan (WU)
- Integrated planning of water resources for irrigation and ecosystems in the Sivash wetlands area, Ukraine – WU/ Institute for Hydraulic Engineering and Land Reclamation of the Ukrainian Academy
- Saline groundwater as a threat to agriculture – Eeman WU
- Saline threats for agriculture, saline opportunities for ecology – Vermue WU-IP/OP

6D. Time planning

The time planning of the main activities of the various projects are given in Appendix 8. It is assumed that the activities can start at April 1, 2010. Given the total maximum duration of the programme of 51 months this means that the last activity should be completed by June 30, 2014. From a planning point of view three types of projects can be distinguished:

- PhD projects, starting asap, lasting four years with a planned PhD defence in spring/summer 2014;
- Professional research projects (Postdocs at Universities, junior and senior researchers at the institutes), lasting between about 2 till 4 years
- Case studies, starting as soon as the contract has been signed, lasting about four years with an overall synthesis at the end of the 51 month period

In the planning the concrete deliverables are indicated by letters: R for reports, W for workshops, P for peer-reviewed articles, PhD for PhD defences, etc. This is done for the individual projects as well as for the overall theme (at the bottom of the table).

6E. Management of the research programme (max. 1000 words)

6E1. Management tasks

The activities in the theme will be managed at three levels: theme level, work package level and project level. Besides daily management activities by the responsible persons involved, formal management meetings will be organized as follows:

- At overall theme management level, involving all 6 Work Package leaders, to discuss progress, constraints, required management actions and opportunities for increased cooperation. This theme-management level is planned to convene 3 times in the first and last year and 2 times in the second and third year.
- At Work Package level, involving all scientists and researchers working in the Work Package (PhD, Postdoc, supervisors, etc.), to discuss progress and results. This Work Package management level is planned to convene 2 times in the first and last year and 1 time in the second and third year.

In addition to above more management oriented activities it is planned to organize regular full programme (theme) meetings with all people involved in the theme. A first meeting is planned about 6 months after the start of the programme when most researchers will have actually started their activities. Subsequent meetings are expected to take place yearly with a final symposium at the end of the programme.

Responsibilities and activities at the three levels are as given below.

Theme level – theme coordinator

- Responsibilities and staff
  - overall management of the activities of the theme (coordination, quality control, reporting, finances, dissemination, etc.)
  - primary contact for the Board and Office of KfC for all strategic activities related to the theme
  - staff involved (all Deltares):
    - theme leader: prof. ir. Eelco van Beek, supported by a deputy
    - deputy theme leader: dr. ir. Ad Jeuken
    - supporting staff: Nicole de Jong-Kolleman
    - communication officer: Margriet Roukema
    - administrative officer: Frits de Graaf
- Activities
  - representation of theme in various internal and external contacts and events
  - review of the progress of the various WP's in relation to the aim and research questions at theme level (see Section 3A1) and the overall planning
  - approval subsidy invoices of partners
  - compilation and final editing of progress reports to the Board, including a synthesis at theme level
  - organisation of theme-level dissemination activities, including web-site
  - support of WP coordinators and project leaders
  - stimulation and support of WP's in their dissemination activities
- Time allocation for this management task: see under 6E2.

Work package level – WP coordinator

- Responsibilities and staff
  - will be responsible for the management activities at WP level (coordination, reporting, etc.)
  - the names of the 6 WP coordinators are given in Section 1C
- Activities
  - representation of WP in theme management meetings
  - review of the progress of projects in this WP in relation to the research questions at WP level (see Appendix 1) and the planning of the individual projects
  - compilation of progress reports of the individual projects in the WP including a synthesis at WP level (above described review)
  - a special management task is foreseen for the leader of Work Package 6 (the integrating case). Together with the overall consortium leader he will be responsible for the linkage between the case studies (addressing the specific questions and issues of the hotspots) and the various research activities carried out in the projects of the other Work Packages.
- Time allocation for this management task: see under 6E2.

Project level – Project leader

- Responsibilities

- management of their project, including quality control, coordination, dissemination, etc.)

- Activities
  - coordination of activities within the project as well as with related activities in other projects, in particular the cases of WP-6
  - representation of the project in WP management meetings
  - progress reporting to WP coordinator
- Budget allocation: budget included in research or supervision costs of the project

In particular for financial matters each partner in the theme will appoint a contact person who will take care of all questions, issues and formalities at institute level, combining the input of that institute over the various projects. That contact person is in principle the first name at every knowledge institution mentioned in Section 1C.

To supervise and advice the management two kind of Boards will be established for the theme:

- A steering group. The steering group will oversee all activities of the theme and will report to both programme management of KfC and the theme management. The composition of the steering group is not known yet but at least will be include representations of the co-financing organizations. As such they can (also) be considered to be a kind of 'Application Board'.
- A Scientific Advisory Board. This group will consist of our international partners as listed in Sections 1C and 3A5. In addition to their direct contribution to the various projects we are planning to have several joint meetings of these experts to comment and advise on the overall approach and progress of the theme.

6E2. Budget for programme management

Costs for programme management activities are explicitly budgeted for management at Theme and Work Package level. Management costs at project level is supposed to be included in the project budget.

Costs management at theme level

	days	rate	costs/yr	
Senior	30	1440	43,2	k€
Support	30	680	20,4	
Communication	20	680	13,6	
Administrative	20	680	13,6	
			90,8	k€/yr
			363,2	k€ for 4 years
PR-material			30	
Material costs symposia			50	
DSA costs international experts			40	
Contingencies			15	
			498,2	k€
		Budget	500	k€

Costs management at WP level

	dagen	rate	kosten/jr	
Senior	8	1200	9,6	k€/yr
			38,4	k€ for 4 years
		Budget	40	k€
			240	k€ for 6 WP's

The total budget for actual management activities is 600 k€ (360+240) which is about 13% of the total budget. This is more than the 7% which is generally accepted as a minimum for commercial projects but less than the 15% that is often mentioned as needed for large joint research projects (such as EU-projects). In addition, the various meetings with stakeholders and experts of other themes within this KfC call justify the relative high management costs.

7 CHECKLIST (to be completed by the applicant)

Nr.	criteria	check enclosed	word count	Page nr.
1	Registration	√		1
1A	Programme characteristics	√		1
1B	Main applicant	√		2
1C	Composition of the research consortium	√		3
2	Main characteristics	√		5
2A	Titles	√		5
2B 2B1 2B2	Summary and overview of the programme Summary of the full proposal Overview of main research questions on three levels	√ √ √	98 313 910	5 5 5
3	Scientific aspects	√		8
3A	Description of the research programme	√	2802	8
3B	Interdisciplinarity	√	293	14
3C	Coherence between work packages and synthesis of outcomes from individual work packages	√	273	14
3D	(Expected) coherence with other research themes in this open call	√	640	15
3E	Connection to finalized and current projects in KfC and other research programmes	√	691	16
4	Societal aspects	√		17
4A	Relevance of the research programme for national and regional adaptation policies	√	686	17
4B	Involvement of stakeholders	√	552	18
4C	Knowledge transfer and valorisation	√	702	19
5	Work packages and projects	√		21
6	Financial aspects, planning and management	√		22
6A	Total budget for the research programme and its distribution across the work packages including motivation	√	794	22
6B	Sources	√		23
6C	Adjacent projects	√		23
6D	Time planning	√		23
6E	Management of the research programme	√	921	23
Appendices 1 and 2				
Work package 1	Boundary conditions	√	774	1
	Project 1.1 Prospects Netherlands under CC	√	1518	13

Nr.	criteria	check enclosed	word count	Page nr.
	Project 1.2 Impacts of upstream developments	√	1806	18
Work package 2	Adapting fresh water supply and buffering capacity	√	973	3
	Project 2.1 Optimization fresh water supply	√	1493	23
	Project 2.2 Fresh water lenses and saline seepage	√	1500	27
Work package 3	Preserving and adapting functions	√	1044	5
	Project 3.1 Salt tolerance response functions	√	1438	31
	Project 3.2 Adaptation to dry and saline conditions in agr.	√	1427	34
	Project 3.3 Salinity and natural systems	√	1491	37
Work package 4	Water technology	√	966	7
	Project 4.1 Water storage	√	1500	41
	Project 4.2 Regional self-sufficient water supply	√	1339	45
Work package 5	Decision making under uncertainty	√	1082	9
	Project 5.1 Adaptation under uncertainty	√	1148	48
	Project 5.2 Robustness analysis methods	√	869	51
	Project 5.3 Toward robust decision making	√	1286	54
Work package 6	Apply knowledge in case studies	√	953	11
	Project 6.1 Case Groene Ruggengraat	√	1343	57
	Project 6.2 Case Haaglanden	√	1326	61
	Project 6.3 Case Zuidwestelijke Delta	√	1268	64
Appendix 3 – Track records		√		1-22
Appendix 4 - CVs		√		23-54
Appendix 5 – Letter of cooperation and commitment foreign research partner(s)		√		1-5
Appendix 6 – Financial aspects A – Total budget B – Sources		 √ √		 - -
Appendix 7 – Letter(s) of intent for co-funding		√		1-10
Appendix 8 – Time planning		√		-

Appendix 1-1

Work package nr . 1	
full title work package :	Climate change in the Netherlands in a global and European perspective – our boundary conditions
work package leader :	prof. ir. E. (Eelco) van Beek
short titles projects	
1.1 Economic prospects of the Netherlands under climate change in a global and European perspective 1.2 Impacts of upstream climate change induced developments for the Netherlands	
PhD:	-
postdoc:	1 - tbn
senior researchers:	prof. Anne van der Veen, dr. Jaap Kwadijk, drs. Aline ten Linde, tbn
other:	tbn
duration:	3 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

What conditions can be expected (evaporation, precipitation, river discharges, sea level rise and consequent salt intrusion and other water quality issues) and what range of conditions should be taken into account to assess the severeness of an inadequate fresh water supply? But also what opportunities does Dutch society have under changed climate conditions? This Work Package will determine the boundary conditions for water management in the Netherlands and place climate change in the Netherlands in a global perspective, in particular in relation to the remainder of Europe and the Rhine/Meuse river basins.

The aim of the Work Package is to provide the water managers and the actual stakeholders with the boundary conditions in terms of *climate and hydrology* and corresponding *economic setting* in which they might have to operate under climate change. The boundary conditions for climate will be taken from KNMI (theme 6) and also the resulting hydrological situation (in particular the river discharges) will be determined in cooperation with theme 6. This will be done for the whole of Europe. The consequent economic effects of drought will be investigated for relevant European countries in general and the Netherlands in particular. Direct and indirect economic effects of increased drought by climate change will be reviewed. Meso- and macro data will be developed to sketch the importance of drought in Europe and the options the Netherlands has under these conditions. Next, and in cooperation with theme 6, building upon earlier national studies ("Klimaatbestendigheid Nederland Waterland", Netherlands Drought Study, ACER project) and European projects (e.g. WATCH, SCENES) consistent sets of boundary conditions for the fresh water use in the Netherlands will be developed, taking into account possible developments upstream in Germany and France with respect to demand and storage. What fresh water shortages will Germany, France and Belgium face and how may they react? What are possible consequences of upstream developments for the hydrology of the river Rhine? For this Work Package cooperation with the German policy-research project KLIWAS will be established.

The central research questions for the Work Package are:

- What are the expected climate changes in Europe and are there differences in expected change between regions and countries?
- What threats and opportunities emerge from (the regional differences) of this change for economic sectors in the Netherlands?
- What will be the effects of climate change on the hydrology in the Rhine and Meuse basins (e.g. discharge, evaporation and precipitation?
- To what increase of salt intrusions will these changes lead?
- What kind of response can be expected from the upstream stakeholders and (regional) governments on the

changed climatologically conditions?
- What will be the impacts of these possible upstream developments for the cross-boundary inflow of the Rhine and Meuse to the Netherlands?
- What are the perceptions of the stakeholders (farmers, firms, etc.) on drought (and possible increased drought) because of climate change and what will be their response action?

B. Interdisciplinarity and coherence between the projects

The two projects within this Work Package are closely related and will develop in parallel. The first project focuses on the (socio-)economic effects of climate change and related threats and opportunities on economic sectors and individuals. This project will be carried out by economists with experience in the water sector. The second project addresses the physical aspects involved in terms of hydrology (rainfall, river flow, etc.) but also the possible developments that upstream users and governments might consider and the impacts this will have on the water availability for the Netherlands. This second project will have a more physical science (hydrology) and engineering (water management) orientation.

The interaction between the two parallel projects is designed so as to establish in project 2 (scenario's for) meteorological consequences (temperature, rainfall, evaporation, etc.) of climate change and the resulting availability of water. Based on this information the economists of project 1 will determine the effects on economic sectors. The responses of the sectors in turn might lead to actions (e.g. different crops, water storage), which will result in hydrological impacts, in particular in terms of water availability. At the other hand, the actions that water managers might take will influence the performance of the economic sectors and the options these have to cope with the new situation. Consequent case study work will be developed in co-operation with Projects 6.1 and 6.3 in a common design for a survey.

C. Stakeholders

The stakeholders benefiting from the research of this Work Package are the national and regional water managers at policy and operational level (DGW, RWS, provincies, waterboards), sectoral representative organizations (Ministries, LTO, etc.) and the actual users of the water (agricultural and industrial companies). The research will contribute directly to (and cooperate with) the Fresh Water Supply component of the Deltaprogramme. It will provide also input to and boundary conditions (hydrological and economic) for some of the other Work Packages, in particular the cases of Work Package 6.

Appendix 1-2

Work package nr 2	
full title work package :	Adapting fresh water supply and buffering capacity of the coupled groundwater- surface water system
work package leader :	Dr. ir. G.H.P. (Gualbert) Oude Essink
short titles projects	
2.1 Quantitative framework to optimize fresh water supply and adaptation strategies 2.2 Fresh water lenses in saline seepage regions under climate stress	
PhD: **postdoc:** **senior research:** **other:**	2 Prof.Dr.Ir. S.E.A.T.M. van der Zee, Dr. V.E.A. Post, Drs. P.G.B. de Louw
duration:	4 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

Surface water quality in Dutch coastal low-lying regions suffers from the combined adverse effects of summer droughts, strong saline groundwater seepage and nutrient fluxes. Ongoing climate change and sea level rise are likely to aggravate these effects and call for adaptation of the fresh water supply - if agriculture and good water quality are to be sustained in these regions (Oude Essink et al., 2010).

Conventional strategies in the Netherlands rely on the intake of fresh surface water from the rivers Rhine and Meuse. This water is used to replenish regional surface water lost to irrigation, evaporation and infiltration to the groundwater system. Large amounts of intake water are used to dilute surface waters and to mitigate the effects of saline groundwater seepage. These conventional strategies may not be robust, as river discharges become more erratic, salt water wedge from the sea intrudes further upstream rivers, water demand intensifies in drier growing seasons and saline groundwater seepage in low-lying areas with controlled water levels increases.

Uncertainty in the spatiotemporal dynamics in the interrelated fresh-saline groundwater and surface water systems on local to regional scale hampers the quantitative evaluation of possible alternative adaptation strategies (Kwadijk et al., 2008). Discharge water rates and the salinity of the discharged water can be extremely variable at a local scale, which makes an accurate quantification very difficult. Yet these processes strongly influence the salinity of surface waters at the scale of water management units like polders (a polder is an area which is protected from water outside the area and which has a controlled water level). The dynamical behaviour of fresh water lenses – vital to sustain agriculture in areas prone to saline groundwater seepage – is highly dependent on spatially variable geological factors and their reaction to climate change is still poorly understood.

This work package is focussed on the question: a. how the spatiotemporal patterns in the fresh water availability in ground- and surface water in coastal low-lying regions will change due to climate change and b. what adaptation strategies can be implemented to sustain water-dependent functions in the future. The two PhD-projects in this work package aim at answering these questions:

- Project 2.1 (*Development of a quantitative framework to optimize adaptation strategies to droughts and salinisation in groundwater – surface water systems under climate change*) focuses on the coupled groundwater – surface water system on the local to regional scale. This project aims at understanding the exchanges between fresh and saline groundwater and surface water in dry periods, to understand the controls on spatiotemporal dynamics in the surface water quality. This understanding is paramount to quantitatively evaluate possible adaptation strategies.
- Project 2.2 (*Increasing the robustness and flexibility of fresh water lenses in saline seepage regions under climate stress*) focuses on the future vulnerability of fresh water lenses at different levels, viz. small (lenses in agricultural parcels), medium (lenses in fossil sandy creeks) to large-scale (lenses in dune areas). These lenses as a part of the groundwater system are important in the aim to minimize the reliance of external

sources of fresh water under saline and drought conditions. This project starts to establish the reaction of these fresh water systems to climate change and adaptation strategies, to establish key factors, and to extrapolate results to other regions. The research starts with in the Zuidwestelijke Delta and then transferring the results to the Provinces of Noord-Holland and Friesland and the Water Board of Rijnland, and finally possibly to areas outside The Netherlands.

Reference:

Kwadijk J.C.J., A, Jeuken, and Waveren, H. (2008), Climate proofing The Netherlands Water land. Exploratory investigation of tipping points in management and policy of the major water system (in Dutch), Deltares T2447.
Oude Essink, G.H.P., Baaren, E.S., van, De Louw, P.G.B., Effects of climate change on coastal groundwater systems: a modeling study in the Netherlands, Water Resour. Res. (submitted 2009).

B. Interdisciplinarity and coherence between the projects

A number of research disciplines will be combined in the defined projects. Project 2.1 focuses on groundwater hydrology as well as surface water hydrology, and on water quantity as well as water quality. Project 2.2 uses a combination of groundwater hydrology, vadose zone hydrology, soil science and agricultural science. Innovative measuring techniques will be used in both projects to quantify groundwater and surface water fluxes and associated solutes.

The projects in WP-2 are closely interlinked, one focusing on the groundwater system beneath an agricultural parcel, the other on the connection of this system to the surface water system. The two projects together cover the entire groundwater – surface water system in relation to salinisation and droughts. The projects will work together in evaluating possible adaptation strategies to ensure sufficient fresh water in the future on both the local and regional scale.

The projects will use results from other work packages and hence other research disciplines. WP-1 is set to translate socioeconomic developments in Europe to projections on the availability of fresh water in the main water system. This data is used as boundary conditions in evaluating possible adaptation strategies. WP-3 uses a biological and ecological approach to investigate the water demand of crops and aquatic ecology. WP-2 and WP-4 together position innovative water technologies in a groundwater - surface water system. KfC theme 6 is aimed at supplying scenarios of the future climate, vital to investigate the effects of different climate projections to the fresh water supply.

C. Stakeholders

Stakeholders are those who have to deal with a limited availability of fresh water in a brackish-saline environment under climate change. They can be divided in three groups: 1. agricultural entrepreneurs who need (supplementary) irrigation for new salt sensitive crops or as a risk management strategy for traditional crops; 2. Water boards and Provincial governments dealing with management issues on the scale of polders; and 3. Provincial and national governments who need better knowledge on the hydro(geo)logy of polders, in relation to nation-wide spatial planning of adaptive and mitigative strategies in a brackish-saline environment.

- Water boards (Zeeuwse Eilanden, Hollandse Delta, Delfland, Schieland, Rijnland, Wetterskip Fryslan)
- Provinces (Zeeland, Zuid-Holland, Noord-Holland, Flevoland, Friesland)
- Agricultural NGO's (LTO, ZLTO, Glaskracht)
- Nature conservation (Natuurmonumenten)

Appendix 1-3

Work package nr . 3	
full title work package: Preserving and adapting functions to limited fresh water supply	
work package leader:	Prof.Dr.Ir. S.E.A.T.M. (Sjoerd) van der Zee
short titles projects	
3.1 Developing Climate Proof Dutch Salt Tolerance Response Functions for Crops 3.2 Adaptation to dry and saline conditions by crop cultivation that exploits brackish water while saving fresh water 3.3 Predicting effects of changing salinity on inland natural systems on the Dutch coastal plain	
PhD:	3
postdoc:	
senior research:	Prof. van der Zee, Prof. Rozema, Prof. Witte, Dr. Paulissen, Dr. Klimkowska, Dr. van Dam, Dr. Metselaar, Dr. van der Ploeg, Ir. Smit, Ir. Roest *(list preliminary and non-exhaustive)*
other:	Ing. Gooren
duration:	4 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

For agriculture/horticulture and nature, adaptation to decreasing fresh water availability is crucial in the growing seasons. Rainfall becomes concentrated in fewer, but heavier showers, the inlet of good quality water from main water courses will be under pressure, while evapotranspirative demand grows. Particularly for coastal provinces, this causes an increasing influence of brackish/saline ground water that upwells or directly enters the water courses. This influences which plants can be grown, at which infrastructural and other costs, whether agri/horticultural production remains sustainable, how nature develops at ‘abandoned’ agricultural areas, and how nature areas and their protection, restoration, and management costs change. A central issue is how agro/ecosystems react to changing salinity. For this reason, the effects of drought and salinity on rural low lands (see WP2) is investigated regarding (i) whether or not current, severely criticized salt tolerance levels of plants are still appropriate, (ii) identifying both economically and environmentally sustainable interesting saline cultures and their management and (iii) the relationships between plant communities and abiotic conditions along fresh-salt gradients, related to management and restoration of nature areas.
Current salt tolerance functions are strongly criticized and a thorough new scientific basis must be developed, that considers periodic instead of only chronic salt/drought stress. These probably lead to more policy negotiation room, affects salt damage re-imbursement costs, and rationalizes fresh water allocation (e.g. is fresh water used for flushing water courses or irrigating cash crops?). For brackish/saline conditions, where conventional cultures show too large yield depressions, new crops that show economic promise will be identified for different salt levels, soils, spatiotemporal variability (particularly with respect to salt concentrations at seedling emergence) and herbicide use, and opportunities to allocate fresh and brackish water with adjusted pricing policies known in economics.
Increasing salinity may pose threats and chances for nature, its management and restoration. To predict nature development directions, a much closer cooperation between the disciplines (e.g. biology/ecology, hydrology) is needed to re-interpret plant community and abiotic site factor relationships, considering that the latter vary strongly in time. This implies detailed monitoring, preferably at different potentially salt affected nature areas) along salt-fresh gradients with zonation of plant communities to appreciate different directions for ecological change and ways to steer manage that change. If changes are perceived as problematic, options for restoration require such insights.

B. Interdisciplinarity and coherence between the projects

All three projects have the salt concentration in soil as the most important variable for (i) agricultural/horticultural yields in conventional and saline cultures, and for (ii) biodiversity and species composition of nature areas (which species can or can not compete). In a first phase, an assessment is needed of how to quantify salinity: as salt concentrations are spatiotemporally variable, hence any chosen measure (e.g. mean concentration in the plough layer) may not be at arbitrary location and time (Van Dam et al., PPO Wageningen, 32.340194.00, 2007). This issue is investigated by all three PhD students in close cooperation.

Each project of WP3 requires experimental work on causal soil salinity and plant response relationships. Both theoretically and regarding use of facilities (e.g. continuous monitoring equipment under field conditions, field locations), a close cooperation ascertains optimal synergy and common methodological approaches.

Although salinity is the controlling factor, other site factors cannot be ignored (e.g. water availability/wetness, pH, redox conditions, nutrient levels). In agricultural production, they affect the yield, whereas they affect which species are feasible in nature areas. For this reason, the three projects are closely related through the impact of salinity, but focus on different aspects, all related with management. In project 3.1 on salt tolerance, the aim is to assess which plants (both cultures and particularly rare/nature plants) grow if saline pressures increase and how management may deal with the risks of drought/salinity yield depressions. Together with project 3.2 focused on both conventional and saline cultures, the management of poor fresh water availability involves salt reduction, adjustment of crop rotation, and the timing of salinity levels for different crops (many plants can cope with some salinity, where often the germination stage is particularly sensitive).

For nature areas (Project 3.3), where salt acts as a filter that may make certain species poor competitors (e.g. birch), some salinity may protect the integrity of the nature areas, making management less cost intensive.

The approach chosen is interdisciplinary, in that it combines in an integrated fashion, soil and water science, plant production and physiological aspects, and needs to be well founded in its regional, management, policy making and economic context, to be of use. The challenge is partly the continuous and intensive dialogue between investigators and stakeholders, for which reason, the definition of questions in the initial phase of the project and the implementation of results is undertaken in WP-6 in close cooperation with stakeholders.

In particular projects 3.2 and 3.3 are intended to have a field site experiments, that require geohydrological and soil characterization, in close cooperation with WP-2 and WP-6. Innovative of all three projects is that new links on pricing of fresh and salt water as an economic tool for water allocation management is given explicit.

C. Stakeholders

Our stakeholders are those that have responsibilities to protect water resources (e.g. through the EU Water Framework Directive) or nature areas (Natura2000), and water use and management in general at different scales (e.g. provinces Zeeland, Zuid-Holland, Noord-Holland, Flevoland, Friesland). Stakeholders that are particularly involved in 'Saline' agriculture are the Dutch coastal provinces Noord Holland and Friesland, companies involved with development of sustainable saline crop cultivation and regional (e.g. LTO Noord) and national institutions (LNV, VenW) dealing with saline agriculture. Sustainable saline agriculture is linked with cultivation of algae, shellfish and fish in the project "Gemengd Zilt Aqua-Agrarisch Bedrijf" (started December 2009, Noord-Holland and Friesland).

Stakeholders such as waterboards (Zeeuwse Eilanden, Hollandse Delta, Delfland, Schieland, Rijnland, Wetterskip Fryslan, see e.g. Hollands Noorderkwartier-Waterbeheersplan 2010-2015), VenW (Nationaal Waterplan, 2009), aim at adaptation of water economics to dry/saline conditions and economic nature protection and development. The projects of WP 3 contribute to technology and economics of e.g. new brackish agriculture, generating new job opportunities and saving considerable fresh water volumes.

HOTSPOTS: Interest in the relationship between water quality and ecology was mentioned by HSOV and in particular the effects of dry years, salt concentrations, and fresh water lens functioning (HSRR, HSWZ). Effects on nature, species and restoration after temporal salinity can only be assessed if salt tolerance is well

enough known.
Both for nature (salt as a filter for unpopular species) and for agriculture, plant responses need to be known. Poor fresh water availability and its allocation strategy needs to account for the salinity that plants can or can not deal with (HSWZ, HSZD, HSRS). Alternative saline cultures were mentioned explicitly by HSRS, and also for nature in this mainport, management costs can be decreased by salt filtering of species.

Appendix 1-4

Work package nr 4	
full title work package : Water technology as a tool box for self-sufficient regional water supply	
work package leader : Prof. dr. P.J. (Pieter) Stuyfzand	
short titles projects	
4.1 Water storage for self-sufficient, regional water supply 4.2 Water technology for self-sufficient, regional water supply	
PhD:	1
postdoc:	-
senior research:	4
other:	-
duration:	4 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

Climate change projections for the Netherlands reveal the risk of periodic shortage of fresh water supply in the future (Loaiciga et al., 1996). During periods of summer drought various parts of the Dutch coastal zone will heavily depend on surface water supply from the major rivers. However, due to the effects of climate change, brackish and polluted intake water from the Rhine/Meuse basin may be more common due to periods of low discharges from rivers and salinity pressures from rising sea levels (Middelkoop et al. 2001; Zwolsman & Van Bokhoven 2007; Van Vliet & Zwolsman 2007; Kwadijk et al, 2007; Oude Essink, 2007). In addition, structural changes in water management are forecast, with profound implications for fresh water availability in especially the Zuidwestelijke Netherlands, in connection with the EU obligation to raise the ecological sustainability of the Deltaworks region. In order to ensure economic sustainability (especially regarding horticulture) and growth in both hotspots 'Haaglanden' and 'Zuidwestelijke Delta', it is crucial to have a sufficient, continuous supply of high quality fresh water, especially in summer. The resulting water stress can be significantly alleviated by storing high quality water when abundant, and by looking at alternative water resources like brackish groundwater and various waste waters, which require treatment prior to use.

WP-4 therefore aims at the following: (1) testing the performance of 2 storage techniques in a brackish groundwater environment, in terms of water quality, storage capacity and recovery efficiency (project 4.1), and (2) making alternative regional water resources, like waste water and brackish groundwater, suitable for use in the greenhouse sector and industry and for flushing the surface water network (project 4.2, link with project 2.1).

The storage techniques are composed of: (a). LSR-ASR, an unprecedented new technology composed of a Leaky Storage Reservoir combined with phreatic Aquifer Storage and Recovery (ASR), with recovery by directly pumping from the reservoir (hotspot Zuidwestelijke Delta); and (b). ASR, a relatively proven technology of aquifer storage and recovery via wells that are used for both injection and recovery (Pyne, 2005; hotspot Haaglanden). Although various small-scale ASR systems are already operational in the region, no monitoring has been carried out to date while lots of problems have been reported due to well clogging, aquifer pollution, the admixing of brackish groundwater and undesired water quality changes due to interaction with very reactive aquifers (PZH 2008).

The alternative regional water resources consist of eutrophic brackish surface water or groundwater, rain water, polluted drainage water and polluted communal wastewater. In a.o. the hotspot Haaglanden some of these resources are being used already, with or without ASR , reverse osmosis (RO) and brine disposal. The situation is running out of hand, because either the treatment and storage systems do not function properly (yielding insufficient water of desirable quality), or the aquifer storage systems and surface water network become polluted; the aquifer by injecting polluted water types, and the surface water by disposal of membrane concentrate or concentrated drain water from the greenhouses (LIT).

The main research questions in project 8 will focus on the following:

1. What are the hydrological and chemical effects of LSR-ASR systems during the filling, storage and recovery

stage, how can their hydrological effects be mitigated, and how can salinization, eutrophication and iron flocculation during abstraction from the reservoir be prevented?

2. How can a LSR-ASR system be optimized in order to also form a buffer against extreme annual anomalies in either supply or demand?
3. How can ASR systems be improved so as to maintain or enhance favorable soil-water interactions (like denitrification and biodegradation of pollutants) while minimizing the negative interactions with the local environment (such as arsenic mobilization)?
4. How can ASR fresh water lenses be monitored and prevented from drifting away due to lateral groundwater flow or buoyancy?
5. How can the suspended solids content of turbid surface or rain water during short peak flows be reduced rapidly and at low cost so that this water can be infiltrated directly without clogging the ASR well or aquifer?
6. How can ASR systems be combined with brackish water reverse osmosis to store and recover desalinized water? (See companion project nr. 9)

The leading research questions in project 9 are:

1. What is the availability and quality of the alternative water resources, and which purification techniques can be applied to make them fit for agricultural or industrial use?
2. Are innovative desalination techniques (like Memstill technology and forward osmosis) feasible along with more common desalination techniques (reverse osmosis and evaporation)?
3. Can membrane distillation-crystallization technology be applied to change membrane concentrate into solid waste (no liquid discharge), and can this be demonstrated on a laboratory scale (2 L/h)?
4. Can membrane concentrate (brine) be disposed of by deep well injection into a deeper, (more) saline aquifer without clogging the well or aquifer and without return flow to the wells pumping brackish groundwater?

B. Interdisciplinarity and coherence between the projects

Within WP-4:
The matching of demand and supply requires storage (project 8) of treated, alternative water resources (project 9). Vice versa, the storage of polluted water in a reservoir or aquifer (project 8) may assist in (further) purifying a treated, alternative water source (project 9).

With other WPs:
Water storage developments are closely related to the groundwater-surface water system studied in WP-2. In addition, the behaviour of ASR fresh water lenses is similar to those studied in WP-2 project 2.2, and as such, knowledge on these lenses will be exchanged.
The output of this study will be used in integral case project 13 (WP6), focusing on the self-sufficiency of fresh water in the region Haaglanden (being the major centre of the greenhouse sector in the Netherlands).

C. Stakeholders

- Provinces of South Holland and Zeeland.
- Water boards (Delfland, Brabantsche Delta, Hollandsche delta, Zeeuwse Eilanden)
- Municipalities.
- Industry and agriculture sector (ZLTO)
- Drinking water companies (Evides, Dunea, Oasen)

Appendix 1-5

Work package nr . 5	
full title work package : Decision making under uncertainty – towards an approach for finding robust and flexible fresh water supply strategies	
work package leader : prof. dr. ir. W.A.H. (Wil) Thissen	
short titles projects	
Project 5.1: Adaptation under uncertainty: resilience as a strategy for climate proofing fresh-water dependent networks of protected areas ("groene ruggengraat") Project 5.2: Robustness analysis methods to support long-term flood and drought risk management Project 5.3 : Towards robust policy making for fresh water supply	
PhD:	1 (drs. Marjolein Mens) – jointly with theme 1
postdoc:	tbn (TUD)
senior research:	Dr. Jeroen P. van der Sluijs and several others
other:	drs A. de Jong(UU)
duration:	4 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

Decision making and planning for fresh water supply are challenging because of different reasons: First, a variety of individual measures or tactics need to be considered at both the supply and the demand side, and appropriate combinations of these need to be made in the process of policy design. Second, different scales need to be considered, such as the local, regional, national and river basin scales, each having their associated governmental bodies. Third, a range of sometimes conflicting interests need to be considered. Fourth, various uncertainties come into play. In addition to the relatively well known natural climate variability, long-term decision making in view of adaptation to climate change brings a new class of important uncertainties. These include the speed of climate change, its impacts on precipitation and evaporation patterns, its impacts on salt intrusion and salinisation, and a variety of possible developments in other fields including transport, land use and agricultural conditions, food markets, spatial developments, economic developments, future technology, and future societal values.
While acknowledging and including the other (notably the multi-actor, multi-objective) complexities mentioned, this work package will in particular focus on the development and testing of approaches to deal with long-term uncertainties in planning for fresh water supply. Clearly, designing policy measures and water supply systems for a 'worst-case' scenario involves the risk of over-investing. But simply ignoring uncertainties and developing policy for a 'most likely' (or a chosen normative future) also involves risks as reality will most likely be different. Conversely, possible future developments may not only imply certain risks, but also provide interesting new opportunities.
During the last decade, it has become accepted that different types of uncertainties should be dealt with differently, depending on the values of the decision makers and contextual conditions (Dessai and Van der Sluijs, 2007 – see projects 5.1 and 5.3). The central aim of the proposed research in this work package is to develop and test tools, and to design guidelines for dealing with the typical uncertainties policy makers have to face when considering long-term policy planning for fresh water supply and demand, at the regional level.

The central research question therefore is:
- What are suitable approaches for finding robust and flexible fresh water supply strategies at the regional level, in light of the various long-term uncertainties encountered?

Sub-questions include:
- What are the characteristic regional fresh water supply situations to be dealt with in the Netherlands?
- What are the relevant uncertainties in each of these, what is their character, and how important are they?
- What analytical approach suits the different uncertainties?
- What mix of policy approaches is recommended for these characteristic situations?
- How can these policy approaches be operationalised for the cases studied in work package 6?.

B. Interdisciplinarity and coherence between the projects

The approach taken in this work package is rooted in the conviction that (a) a number of key uncertainties cannot easily be reduced and have to be accepted, and (b) different approaches will be needed for different types of uncertainties in different situations. We postulate that two main strategies will be relevant. In the first, water supply systems are designed to be sufficiently robust. Robust *systems* will be able to function – or quickly recover and restore functioning after disturbed – under a variety of conditions and/or disturbances, without external intervention in the system. Various approaches and mechanisms may contribute to system robustness, such as built-in feedbacks and recovery mechanisms, diversification, redundancy (see project 5.1). This strategy seems best fitted for uncertainties where natural variability is a key characteristic, such as weather conditions.
In the second strategy, labeled 'robust *decision making'* or 'adaptive policy making', a policy strategy is chosen that explicitly considers and includes options for deliberate policy *adaptation* as the future evolves. This strategy seems to best suit situations characterized by so-called 'deep uncertainties': a variety of developments are thought to be possible and can significantly impact policy outcomes, but information about their probabilities and/or consequences is scarce or even absent (scenario-uncertainties, or so-called wild cards). In addition, stakeholders may disagree about the best system representation and about the valuation of alternative outcomes.
For fresh water supply in the perspective of climate change, both variability and deep uncertainties are relevant. Hence, the proposed research in this work package will explore both approaches, in three complementary projects:

- Project 5.1: Adaptation under uncertainty: resilience as a strategy for climate proofing fresh-water dependent networks of protected areas (with special emphasis for the "groene ruggengraat")
- Project 5.2: Robustness analysis methods to support flood and drought risk management
- Project 5.3 : Towards robust policy making for fresh water supply.

Both projects 5.1 and 5.2 will focus on robustness principles for socio-ecological systems, in particular protected natural areas, resp. flood protection and water supply systems. Both will primarily be oriented to dealing with variability uncertainties and preventing or reducing undesirable outcomes.
Project 5.3 will be complementary to projects 5.1 and 5.2 in three respects: it will focus on overall *policy* strategies as deliberate interventions in socio-ecological systems including adaptive policy actions over time; it will be mainly oriented to *deep* uncertainties, and it will also explicitly explore *opportunities* that future uncertainties may hold..
Project 5.3, in addition, will take the lead in combining insights, i.e., for a given situation, which (mix of) approach(es) will be best fitted?
Each of these projects is interdisciplinary in itself, combining water-related knowledge with ecosystem knowledge (project 5.1); and with socio-economic knowledge (projects 5.2 and 5.3).
In identifying possible solutions, this work package will build, among other things, on the findings in work packages 1 (for socio-economic conditions and scenarios), 2 through 4 (for possible solutions), and 6 (providing more detailed and full information on the case studies to be elaborated). Conversely, the case-based more in-depth uncertainty analyses performed in WP5 will directly feed into WP6.

C. Stakeholders

Finding appropriate ways of dealing with the variety of uncertainties is in the interest of all stakeholders and policy makers involved in fresh water supply.
As the WP5 research team will actively contribute to the cases that are further elaborated in work package 6, interactive sessions with the key stakeholders in these cases will be organized to discuss the identification and relevance of uncertainties, identify policy options, and in general discuss and evaluate the uncertainty analysis and policy approaches from stakeholder and policymaker perspectives. In addition, as the workpackage intends to contribute approaches to dealing with uncertainties in water supply a more general sense, other key stakeholders such as DGW will be invited to contribute their views and react to research findings and recommendations.
Finally, to ensure inclusion of expert subject knowledge, and to foster dissemination of the concepts and approaches to be developed, part-time involvement of senior staff of Deltares, KWR and Alterra is foreseen.

Work package nr 6	
full title work package : Applying knowledge in case studies	
work package leader : Ir. J.A. (Jeroen) Veraart	
short titles projects	
6.1 Case study Groene Ruggengraat 6.2 Case study Zuidwestelijke Delta 6.3 Case study Haaglanden	
PhD:	PhD candidates from WP-1,2,3,5 will be part of the research team.
postdoc:	Postdocs of WP-1,4 and 5 will be part of the research team
senior research:	Senior staff of Alterra (J.Veraart, S.Werners, M. Bakker), Acacia-Water (A. de Vries), Deltares (A. Jeuken), TNO (R.Creusen) and KWR (M.Paalman) will be involved.
duration:	4 years

Description work package (max. 1000 words – A through C)

A. Problem definition, aim and central research questions

In work package 6 we aim to identify viable adaptation strategies built upon scientific knowledge from WP-1-5 and practical experience in freshwater resources management. These strategies should consist of a mix of measures and interventions that aim to optimize water demand and water. During the execution of the research programme the interaction between the stakeholders and research activities within the other work packages will in particular be organized through WP-6 in the three integrating cases:
a. ‘Haaglanden’, viz. “Improving regional self support of Greenhousing and Industry in the Westland area”;
b. ‘Zuidwestelijke Delta’, viz. “climate proof, and sustainable water use in the southwest Dutch Delta area” and
c. ‘Groene Ruggengraat’, viz. “combined adaptation for agriculture and nature in the ‘Groene Ruggengraat’.

For each case study a working group and steering group (waterboards, provinces) will be created consisting of relevant project leaders of WP1-5, stakeholders and key persons in relevant science-policy interfaces (programme office Zuidwestelijk-Delta, KNDW, programme office Waterkader Haaglanden). This working group is responsible for tuning stakeholder interactions (workshops, interviews, surveys. In each case study informal meetings are organized (frequency once a half year) to assure that practical experience in freshwater resources management is enriched with research results and the other way around. In addition a number of formal meetings with stakeholders will be planned.Researchers will be working partly on location at the office of relevant stakeholders (province, water board)

In the 3 working groups of the cases joint fact-finding (Eerman and Stinson, 1999) between involved scientists and practitioners and policy makers will be stimulated. In short, employing joint fact-finding means addressing a factual dispute by forming a single fact-finding team comprised of experts and decision-makers representing both sides of the dispute (Schultz, 2003). The factual dispute(s) to be discussed in the workshops is built upon the main objective of the research proposal, the aim to find solutions for the growing mismatch between freshwater supply and demand in the short- (2015) and long term (2050/2100). Amongst others, disputes to be discussed are:

- The level of (dis)agreement about the sense of urgency to tackle this issue (problem framing)
- Water demand management versus water supply management (costs and benefits)
- The (perceived) level of ‘no-regret’ of proposed strategies/measures on case study level
- Resilience approach versus Robustness approach (in co-operation with WP-5)

Lessons learned in the field of ‘action based research’ will be embedded into our approach in case study ‘Haaglanden’ in collaboration with KfC theme 7 (Erasmus University, Arwin van Buuren).

This tailor-made local approach has the risk that water scarcity problems are transferred from one region to the other. Work package 6 aims to identify these risks of problem shifting, in close collaboration with work package 1 and 5. In collaboration with WP1 (Anne van der Veen), KfC *project “ Negotiating uncertainties:* defining climate proofing and assessing associated uncertainties in the Southwest Delta Region of the Netherlands” and KfC theme 3 (Rural Areas) consultation of stakeholders in fresh water resources management (in particular agriculture, nature conservation) are planned. Also TNS-NIPO and ZLTO within (a selection of) the case studies will be invited to these consultations. These consultations include internet surveys and interviews. The general objective is to assess how resilient individual agricultural entrepreneurs are regarding economic drought and salinity damage and how they deal with uncertainties. The results are used for Agent-Based modelling (KfC theme 3), Exploratory Modeling/Analysis (WP-5) and guidelines for dealing with uncertainties in negotiating processes (KfC project Negotiating Uncertainties in collaboration with WP5).

Deliverables

Each case study has its specific deliverables. In addition it is our ambition to wrap up and to integrate the results from the case studies in co-operation with work package 5. The involved PhD's are stimulated to become involved in multi-disciplinary publications based upon the results of the case studies.

- Qualitative Description of local portfolios with measures to cope with salt, flood and drought risks supported by both scientific knowledge, practical expertise and treatment of uncertainties
- Quantitative assessment of (future) freshwater supply, fresh water demand and the water balance on local level (salinity and quantity).
- For each case study a multi-author popular article will be published
- 1 peer reviewed article that will reflect on the level of achieved inter/multi/transdisciplinarity within the 3 case studies and the usefulness of the chosen approach
- Applied Prototype experiments in the field of water technology (desalinization concepts, brine treatment and injection techniques, reuse of waste water, storage of surface freshwater in aquifers)
- A paper on the generic aspects of strategies towards a sustainable water management system in low lying areas

B. Interdisciplinarity and coherence between the projects

For each case study knowledge regarding measures will be *combined* and *tailored* to the local circumstances in dialogue with local experts and stakeholders. Two policy paradigms are currently used in policy making regarding approaches to climate proof fresh water resources management in the Netherlands (Design National Water Plan, 2008):

(a) Resist impacts of climate change on fresh water resources
(b) Cope and live with the impacts of climate change on available fresh water resources.

Within those two main policy paradigms combinations of measures are sought that increase the *robustness and/or resilience* of freshwater supply and the use of water (. A second approach, labeled as *adaptive policy making*, explicitly considers and includes options for deliberate adaptation as the future evolves. In each of these regions similar *timeframes* for the main interventions to achieve are used, i.e. short term (2009-2015), medium term (2015-2050) and long term (2050-2100).

A project team with representatives of all consortium members and WP's takes care for integration of the results of the 3 projects, including dissemination of generic lessons learned that are also worthwhile for other case studies within KvK and other delta's. The project team takes care for the co-operation with the other work packages and with other KvK research projects.

C. Stakeholders

Project 6.1: *Province Noord-Holland, Province Zuid-Holland. Province Utrecht, Waterschap Schieland en Krimpenerwaard, LNV, DLG, Programmabureau Groene Hart*

The Dutch government decided in 2009 to invest 113 million Euro in the peat meadow areas during the period 2010-2015 (in Dutch: Uitvoeringsprogramma FES Westelijke veenweiden and Randstad 2040: inrichting van een Groene Ruggengraat). The investments aim to synchronize spatial claims for nature, agriculture, construction and water management, supported by knowledge developed by national research programmes (Habiforum, Leven met Water) and applied by the programme offices Groene Hart (www.groene-hart.nl), Laag-Holland (www.laagholland.nl) and project Hollandsche Ijssel (www.schonermooier.nl). The available science-policy interfaces and stakeholder networks of these organisations will be used in project 13.

Project 6.2: *Province Zeeland, ZLTO, DLG, Provincie Brabant, Waterschap Brabantse Delta*
This project will make use of the stakeholder networks of two the Knowledge Network Delta Water (KNDW) and the program office ' Zuidwestelijke Delta' (www.zwdelta.nl) . The programme office ' Zuidwestelijke Delta' falls under responsibility of a steering committee that include high-level policy makers of the ministry of V&W, regional water boards and provinces.

Project 6.3: *Waterkader Haaglanden, Province Zuid-Holland, Waterschap Delfland, Glaskracht, NLTO, Waterschap Hollandse Delta, PPO Glastuinbouw-Naaldwijk (Wageningen UR)*
In project 15 an advisory board comprised of local experts will be established in which above mentioned institutions will be involved. Workshops and interviews with stakeholders will built upon the established public-private partnerships by Water Framework Haaglanden (www.waterkaderhaaglanden.nl), in Dutch 'Waterkader Haaglanden'. This is a cooperation between the water authority Delfland Water Board, the Province of South-Holland and the City Region of Haaglanden with its nine municipalities.

Appendix 2-1

Project 1.1 (with work package 1)	
full title project :	Economic prospects under climate change in a global and European perspective
project leader:	Prof. dr. A. (Anne) van der Veen
type of research:	Postdoc
duration:	3 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

In recent reports of the IPCC (Easterling, et al., 2007) attention has been given to the effects of drought worldwide. The effects mainly focus on food security in developing countries. Drought as the consequence of extreme effects of climate change, however, also will affect developed countries: long periods of drought will influence vegetation, biodiversity, agriculture, fresh water quality, quantity of cooling water and consequently efficiency of industrial production.

In this project we will investigate literature on the economic effects of drought in Western European countries in general and the Netherlands in particular. The methodology to establish direct and indirect economic effects will be reviewed, incorporating the already established methodologies to compute the economic effects of disasters. Moreover we will come up with micro- and meso data to sketch the importance of the phenomenon.

Within the literature on disasters a fierce discussion still takes place on the issue of vulnerability (Adger, 2006) and resiliency (Birkmann, 2006; Folke, 2006; Fussel, 2007). Matters of definitions shade however the urgent need to sketch how resilient societies are to disasters in general and drought in particular. Within the discipline of economics major steps are being made now especially on the meso level of economic sectors (Rose, 2004). In this project we want to extend this expertise to the level of individual firms (the micro level) in order to measure whether and how firms are able to cope with drought.

Consequently, the aim of this project is to develop a methodology that captures the economic effects of drought on a meso- and micro level, and to apply this methodology to our hotspots.

In the recent discussions in the Netherlands on how vulnerable the country is for flooding, the economic methodology to assess vulnerability focused more on mitigation than on adaptation strategies. Drought and increased salinity, as a new challenge for Dutch society, requires a clear spotlight on adaptation. That implies a rethinking of our economic models that try to capture these effects: Not only on a meso level, where forward and backward chains multiply exogenous shocks, but also on a micro level. On this micro level, firms will adapt, e.g. through innovation, dependent on how they perceive the dangers of fresh water supply.

Therefore, the research questions for our project are the following:

1. What are the threats and emerging opportunities from climate change for economic sectors in the Netherlands?
2. How can we develop a new methodology that covers economic consequences of drought/salinity on a meso- and a micro level?
3. Is it possible to design policy measures of economic resiliency on both levels?
4. What are the outcomes of our analyses for some specific hotspots?

B. Approach and methodology

Drought in the Netherlands is a known issue, mainly researched by ecologists. For economists the issue becomes more and more important, because the functioning of the economy itself is at hand in case of dramatic changes in freshwater supply. Recently, several projects devoted (although rather scattered) attention to drought and consequences for Dutch economy: Sites like www.helpdeskwater.nl and www.droogtestudie.nl summarize research output. It is however apparent that most output is delivered by civil engineers. In Ecorys (2003) one of the few attempts to estimate damage to the Dutch economy is presented. Interestingly, on page 19, it is concluded that no detailed information for particular agricultural sectors was available to assess effects of drought. Ecorys applied a meso scale input-output model to estimate economic effects. Recently Agricom (see helpdeskwater.nl) was developed as a combined hydrological/economic model that enables to compute costs for the agricultural sector. However, this model is not combined with the meso and macro economic scale.

In the past economists devoted a lot of attention to flood damage to the macro economy and to the meso level of particular economic sectors (Bockarjova, Steenge and van der Veen, 2004a and 2004b). This damage estimation required a special methodology, dependent on input-output modeling. Specifically the point of resiliency got more and more attention with respect to the question how sectors and firms could cope with discontinuities in their production and in their demand and supply structures (Rose, 2002). Basically, it is important to estimate the redundancy in an economy in order to assess the vulnerability to a disaster (van der Veen and Logtmeijer, 2005). Measuring economic effects of drought will contain major parts of the flooding methodology, but also differs in important respects. Floods are sudden shocks that create disruptions in production, and discontinuities in demand and supply of products. However, drought and salinity develop slowly and require water to be handled as a resource. That implies that attention should be given to behaviour of individual firms (the micro level) and their coping strategy in case of disruptions in the supply of fresh water.

In this project we will focus on the meso and micro level in order to research adaptation strategies on firm level and matters of redundancy on a sector level. Macro data will be handled exogenously.

Collaboration will be established with Theme 7 and 8, with other economists. In Theme 8 a hydro-economic model is developed which, in our observation, is complementary to our micro approach.

In Theme 7 economic incentives are being investigated. These ideas and consequent results will be handled as input in our firm survey in order to test for resiliency.

An interesting corollary is to investigate behaviour of firms with respect to the risk of drought and/or salinity. A relation can be made with the literature on disaster management and risk communication on measuring intentions and motivations of individual firms to take adaptive measures (Maddux and Rogers, 1983; Martin, Bender and Raish, 2007). This concept has been applied in the recent BSIK project PROMO in Leven met Water, where the project leader participated. For the 2009 technical PROMO reports see http://www.itc.nl/Pub/Home/library/Academic_output/Working_papers_series.html. An important element will be to differentiate between individual measures and collective actions. In this Project we will question individual firms on attitudes, intentions, and on the role of, and trust in, government.

To research the economics around the problem of drought and salinity we will:

1. Investigate the literature on the economic effects of drought in Western European countries in general and the Netherlands in particular.
2. Outline the importance of the phenomenon of drought for the Dutch economy in relation to fresh water supply, based on available information for economic sectors in Dutch (CBS) statistics.
3. Pay attention, on a micro level, to the question how resilient individual actors are in coping with problems of drought. To do so we will in collaboration with Project 6.1 and 6.3 survey individual firms in order to research the role of fresh water in production, the possibilities to adapt to a change in the supply of fresh water, their perception of the risk involved and (technical and economic) strategies to deal with the issue. Here a differentiation between measures of individual agents and the collective is made. TNS/NIPO will be asked to do the survey under our guidance and control; 75 firms will be questioned and asked to send in their forms.
4. Assess firm strategies to cope with drought and increased salinity on a meso level on basis of the methodology in Agricom.
5. Research redundancy on a sector level by extending the Agricom methodology.

C. Scientific deliverables and results

With respect to this project we expect to come up with the following results and deliverables:

1. A short literature survey on the economic effects of disasters in general and drought in particular.
2. An investigation of the importance of possible drought for the Dutch economic situation.
3. A methodology for computing damage to firms and economic sectors due to drought and decreasing amounts of fresh water.
4. Estimation on the meso economic level of redundancy by assessing direct and indirect economic effects of drought in the Western part of the Netherlands.
5. A survey design for investigating
    a. Technological and economic aspects of fresh water supply,
    b. Risk perceptions of drought and salinity, and
    c. Consequent economic behaviour.
6. Statistical analysis of a survey under 75 firms of economic aspects of fresh water supply, risk perceptions, motivations and intentions of economic behaviour.

D. Integration of general research questions with hotspot-specific questions

The project will increase our understanding of behaviour of individual firms in a more saline environment/ under heavier drought conditions. Consequently, the project will sketch the effects on a meso economic scale of these changing conditions. It is clear that changes in external conditions might have severe consequences for Fruit Cultivation and Horticulture, and therefore on production and employment as is also researched in Project 6.1 and 6.3.

E. Societal deliverables and results

There are a few apparent economic sectors that will suffer from drought; the obvious ones are agriculture and horticulture. This project is meant to sketch and research the vulnerability of these important sectors to the Dutch economy. We will establish how resilient firms within these sectors are in coping with alternatives.
However, there are other sectors in the Dutch economy that will be attached by future drought. Fresh water is used in some industries as cooling water (electricity production). Moreover, drought may also lead to transportation problems.
This project will deliver a general description on the consequences of drought for sectors in the Dutch economy and it will produce detailed micro results on basis of comprehensive surveys per firm.

F. Most important references (max. 15)

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Appendix 2-2

Project 1.2 (with work package 1)	
full title project :	Impacts of upstream climate change induced developments for the Netherlands
project leader:	Prof. Eelco van Beek
type of research:	Applied
duration:	2 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Climate change will not only have its impacts on the Netherlands but will affect our upstream countries Germany, Belgium, France, Luxembourg and Switzerland as well. It can be expected that these countries will take adaptive measures to cope with these changes. Of particular importance for the Netherlands are those measures that will further decrease the inflow to the main rivers or measures that will increase the extractions from the river. The ultimate result for the Netherlands will be that the cross-boundary inflow to the Netherlands will be reduced. In previous research on climate change impacts for the Netherlands (KNMI, RWS/WD, Deltares) only the 'natural' reduction of the inflow because of climate change has been taken into account. The possible impacts of upstream measures have been ignored. Under extreme conditions (dry years under G+ and W+) these impacts might be considerable and should be taken into account. This research project will try to quantify these impacts.

The ultimate aim of the research is to derive various scenario's of the effects of climate change and upstream developments on the cross-boundary inflow to the Netherlands. The underlying research is based on the following central research questions:

1. What are the expected impacts of climate change on drought in the upstream parts of the Rhine and Meuse river basins?
2. What are likely adaptive measures that upstream users and water managers can take to cope with these impacts?
3. What are the consequences of these measures in terms of cross-boundary inflow to the Netherlands?
4. What are the resulting boundary conditions for the various hotspots in the country?

B. Approach and methodology

The research will be carried out in close cooperation with theme 6, in particular for the first and last central research questions. Cooperation will be established with research organizations in the upstream countries at applied and academic level as well as the international commissions involved (IRC – International Rhine Commission; ICBR – International Commission for the Protection of the Rhine; IMC – International Meuse Commission). Close cooperation with the German policy-research project KLIWAS will be established. The Federal Insitute of Hydrology (dr. Thomas Maurer) is included as foreign partner in the project.

Approach and methodology to answer research question 1

- application of Regional climate model results forced by different Global Climate Models for different SRED emission scenario's, including bias correction.
- comparison with model results of national research institutes
- determination of spatial and temporal differentiated scenario's for rainfall and potential evaporation

Currently in the Netherlands the KNMI 2006 scenarios form the starting point for water resources management assessments. However, these scenario's will be replaced within due time. An important project which results will probably be used for an update of the KNMI 2006 scenarios is the ENSEMBLES project. The ENSEMBLES project provided a great number of climate scenarios for Europe derived from different AOGCM-RCM combinations using a forcing according to different SRES emission scenarios. The project is jointly carried out by a great number of meteorological offices and research organizations. The ENSEMBLE projections are the results of global climate model outputs, dynamically downscaled using high resolution regional climate models. Currently the RHINEBLICK project is using these results to arrive at water scenario's for the river Rhine basin that have commitment from the different Rhine countries. In 2010 for the River Meuse a comparable project (AMICE) will start. This project will (among other) provide discharge scenarios for the river Meuse, based on the same ENSEMBLE projects. So far the production of scenario's is in its early stages. The idea is that this project will make use of the work that has been done in the ENSEMBLE project and combine it with the results for the RHEINBLICK and AMICE projects. Also for our fresh water theme we consider it of utmost importance that we base our scenarios on internationally accepted boundary conditions. ENSEMBLE provides precipitation, evaporation and temperature data from the following AOGCM-RCM combinations:

Institute	Global Climate Model	Regional Climate Model	IPCC scenario
C4I	ECHAM5	RCA	*A2*
C4I	HadCM3	RCA	A1B
CNRM	ARPEGE	Aladin	A1B
DMI	ARPEGE	HIRHAM5	A1B
ETHZ	HadCM3	CLM	A1B
HC	HadCM3	HadRM3	A1B
HC	HadCM3	HadRM3	A1B
HC	HadCM3	HadRM3	A1B
KNMI	ECHAM5	RACMO	A1B
METNO	BCM	HIRHAM	A1B
MPI	ECHAM5	REMO	A1B
OURANOS	CGCM3	CRCM	A1B
SMHI	ECHAM5	RCA	A1B
UCLM	HadCM3	PROMES	A1B

The RHEINBLICK project will provide projections using the raw AOGCM results, the raw AOGCM-RCM combination results as well as the bias corrected results. These will be used to assess the range of possible future weather conditions, including an assessment of the magnitude of the uncertainty due to different sources. As the ENSEMBLES project only includes the A1b and A2 (only one run) emission scenarios the climate scenario's will be extended with other AOGCM results. At Deltares the results of all 4th assessment IPCC report AOGCM's for the River Rhine and Meuse are available. Also a simple bias correction scheme has been developed. The analysis will be extended with these results.

So far the scenario's for changed climate conditions have only be analysed on their effects of the regime of the River Rhine. In this project it is the idea to develop more tailor made climate scenarios for application in water supply studies. As such the results will also form a boundary condition for evaluating drought management plans already available in the upstream countries.

Approach and methodology to answer research question 2

- determination of impacts of cc scenario's for use functions, in particular agriculture
- literature review of adaptive measure considered in upstream countries
- inventory of drought management plans
- determination of impacts

In particular this part of the project will be carried out in close cooperation with institutes in our upstream countries. Depending on the availability of data and models that describe the relation between meteorology/hydrology and economic functions in those countries (comparable with NHI in the Netherlands) we will determine the spatial differentiated impacts of the climate change scenarios on these economic functions. This will be done in cooperation with the economists of project 1.1. It is expected that the main impacts will be on agriculture. If specific models are not available estimates of agricultural damage will be made by using general crop production functions.

The size of the impact in combination with the hydrological situation will determine if and adaptive measures are feasible. We do expect that some sort of inventory of such measures will be available in existing development and management plans in the various sub-basins. These will be collected and where needed extended to get a comprehensive picture of possible developments. In workshops with the water managers involved we will develop several scenarios for these upstream developments and determine, again in cooperation with project 1.1, the impacts these scenarios have on the economic sectors. Emphasis will be on those impacts in upstream countries that will influence the performance the same sectors in the Netherlands, in particular agriculture and shipping.

Approach and methodology to answer research question 3

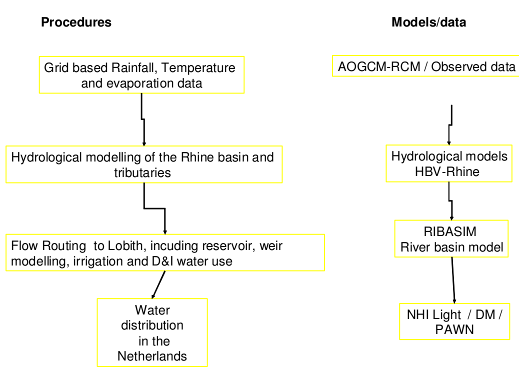
- application of HBV to determine rainfall-runoff conditions
- application of water balance model at river basin level (RIBASIM)
- application of SOBEK to determine impacts on water levels (for shipping)

Discharge scenarios for the River Rhine using the raw ENSEMBLE AOGCM-RCM output data have been produced in the RHEINBLICK project. For the river Meuse, no runs have been produced yet, however the data and models to be used for the production of such discharge scenarios are available at the KNMI and Deltares. The idea in this project is to produce scenario's for both rivers and include an assessment of different sources of uncertainty to them. The sources of uncertainty that will be incorporated are: natural variability, uncertainty due to model errors of the AOGCM's, due to the RCM's, and due to the use of different hydrological models. The importance of the different uncertainty sources will change in time.

In this research project the discharge scenario's resulting based on the ENSEMBLE results will be translated into scenario's relevant for analysis of water supply to the Netherlands. To do so, we will start using the system that is currently in use in the Netherlands to provide discharge scenarios for the river Rhine (FEWS-GRADE RHINE). The core of this system is the HBV-Rhine hydrological model. Currently an experimental system to simulate the effects of climate change on the Rhine/Meuse basin, including the delta is developed in the KvK–KKF-coupling project. We anticipate that this system can be used for running these scenarios next year. This system will allow for using different hydrological models.

The FEWS-GRADE RHINE/MEUSE system has specifically been developed for flood assessment applications. Therefore, water abstractions, reservoirs and water diversions as (including scenarios for new developments as determined in the previous project component) are not well represented (or not at all). It is therefore that we propose to develop a water distribution modelling system based on the RIBASIM software. The runoff in this system will be simulated by the HBV-Rhine model (or others once the experimental system is ready). The drainage and distribution of the water along the river branches will be simulated by the RIBASIM application.

Flow chart water system



The ultimate result of this component will be various scenarios for water availability (time series of river discharges) at the border of the Netherlands.

Approach and methodology to answer research question 4

- What does this mean for external boundary conditions, e.g. Gouda?
- What will be the internal boundary conditions, rainfall and evaporation?

This last component will provide the boundary conditions for the case studies of WP-6. The time series at the border of the Netherlands will be translated in water availability at the various intakes of our integrating cases. This will be done by using the existing NHI modeling framework. When specific information on internal boundary conditions such as local rainfall and evaporation is needed for the case studies this project will support the case studies in retrieving the right data from WP-6.

C. Scientific deliverables and results

The ultimate result of this project will be combined climate change and upstream developments scenarios and the corresponding impacts for the Netherlands in terms of the cross boundary inflow of the Rhine and Meuse. So far jointly developed comprehensive scenarios have not been made yet. The methodology that we will use is state-of-the-art. The inclusion of possible upstream developments that will influence the water availability for the Netherlands has certainly not been touched upon before. Specific scientific deliverables are;

- Research reports containing the findings on the central research questions
- Scientific articles (peer reviewed) summarizing these findings

D. Integration of general research questions with hotspot-specific questions

The relation of this project with the hotspot-specific questions is mainly in providing the hotspots their fresh water boundary conditions for their intakes as a result of climate change and upstream developments. In combination with the research carried out in WP-2, WP-3 and WP-4 answers will be given to their questions on threats and opportunities. The integration will take place in WP-6 for the 3 selected case studies.

E. Societal deliverables and results

For the hotspots the most important societal deliverables and results are given above. The boundary conditions will determine the threats but also opportunities for the economic sectors. At the level of the Netherlands the resulting boundary conditions (the scenarios) are an important input for the Fresh Water project that is presently being carried out as part of the Delta programme.

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Appendix 2-3

Project 2.1 (with work package 2)	
full title project :	Development of a quantitative framework to optimize adaptation strategies to droughts and salinisation in groundwater – surface water systems under climate change
project leader:	Gualbert Oude Essink
type of research:	PhD
Duration:	2010 – 2014

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

In coastal regions, like the western part of the Netherlands, fresh water availability and delivery are adversely affected by summer droughts and saline groundwater seepage. Ongoing climate change, land subsidence and sea level rise are likely to aggravate these effects and call for adaptation of the current water management strategies to safeguard the supply of fresh water (Oude Essink *et al.*, 2005; Hoogvliet *et al.*, 2007; Kwadijk *et al.*, 2008).

In the Netherlands, a dense network of subsurface drains, ditches and canals serves to maintain groundwater levels and to discharge excess water. The surface water network is also used to deliver fresh water during periods of drought. Discharge of groundwater into surface water bodies like canals occurs via upward seepage. At the same time, infiltration of surface water results in groundwater recharge. Groundwater and surface water are thus closely linked. Both the exfiltrating and infiltrating water can either be fresh or saline. Many processes, such as groundwater discharge, are spatially variable at a local scale. Discharge rates and the salinity of the discharged water can be extremely variable at the scale of meters, which makes their accurate quantification very difficult (Griffioen *et al.*, 2002; Louw, *et al.*, 2008). Yet these processes do strongly influence the salinity of surface waters at the scale of water management units like polders.

Our present understanding of the response of the coupled groundwater – surface water system is still insufficient (Sophocleous, 2002). The prime reason is that local-scale processes are not captured by regional quantitative models. These models can therefore not be used to make reliable predictions of the future effect of climate change or to assess the suitability of adaptation measures.

Aim

The main objective is to develop a quantitative framework for assessing the volumes and fluxes of water and dissolved salt within the hydrological system. This research project aims to design adaptation strategies to adequately mitigate the adverse effects of climate change in coastal low-lying water systems. Conceptual and mathematical models of the effects of climate change on groundwater – surface water interaction and salinisation will be developed, which will be used to investigate the effectiveness of a variety of possible adaptation measures, both on the local scale (intelligent drainage design, fresh water buffering, level management) and the regional scale (regional water management, flushing, separating discharge and allocation routes).

Central research questions

The central research questions are focused on how groundwater – surface water systems react under climate change at different scales and how optimal adaptation strategies can be optimized:

1. How can groundwater-surface water interaction be quantified and what are the fluxes of water and dissolved salt between surface water and groundwater?
2. How can local-scale processes be accounted for in regional models?
3. How much fresh water is really needed to flush salinised water in ditches and canals and is fresh intake water really reaching the ditches where it is needed?
4. How will future climate change affect groundwater-surface water interactions and hence the availability of fresh water?

5. What adaptation strategies are best suited to ensure the availability of sufficient fresh water?

B. Approach and methodology

The first step in the development of the quantitative models is to integrate all existing knowledge of groundwater-surface water interactions in coastal low-lying areas, particularly in the Netherlands. Recent investigations show that at the local scale sharp gradients in salinity and temperature suggest that fluxes across the sediment-water interface occur at the scale of meters to decimeters (Louw, et al. 2008; Oude Essink et al., 2009). These recent findings call for a re-evaluation of current conceptual models of salt transport between the surface and subsurface compartments of the hydrological system. One component will focus on measurement of surface-groundwater interactions (viz. water and salt fluxes) at the local scale and quantification of its variability using observation wells, flux meters, geophysical techniques (CVES, ERT) and temperature sensors (Anderson, 2005). The purpose is to identify the sources, sinks and pathways of different water types within a water management unit (like a polder) and to determine the dominant processes that control spatiotemporal variations of water salinity.

Secondly, a quantitative framework will be developed to improve the conceptual understanding of the groundwater-surface water system. A quantitative framework is paramount in assessing the effects of a changing climate on groundwater-surface water interaction and the salinisation of ditches and canals, and in evaluating possible adaptation strategies. The framework should be designed to be suitable to assess both effects of changing boundary conditions (climate change, societal developments) and the effects of measures to the availability of fresh water in the local and regional water system. Relevant processes include an adequate description of groundwater discharge / recharge and associated solutes (a.o. salt), varying water demands of water users (open field agriculture, glass houses, ecology), hydraulics in ditches and small waterways, fresh water availability in the main water system and regional water management strategies. Various methods for describing the physics of the mechanisms operating at the GW–SW interface as well as current model frameworks (e.g. Kolditz et al., 2008; Sudicky et al., 2006; Langevin et al., 2005) will be reviewed and tested for their applicability to the conditions in the study areas. Part of this research will be conducted in close collaboration with the British and U.S. Geological Surveys.

Effects of climate change on the water demands of the different water users are investigated in collaboration with WP-3. Societal developments and the availability of fresh water in the main water system will be derived from WP-1. Different realisations of future climate conditions, results from calculations using regional climate models, will be made available by KfC research theme 6. These realisations will be downscaled to the appropriate spatial resolution and be used as forcing data in the quantitative framework.

Using the quantitative framework, different adaptation strategies to ensure the availability of fresh water will be evaluated. Which strategy is best suited to mitigate the likely adverse effects of climate change on the availability of fresh water? Which measures are no-regret measures? Which measures are widely applicable, and which are only suitable for specific conditions? Strategies will be selected after consulting the different WPs and in close consultation with the KfC hotspots.

C. Scientific deliverables and results

- Four scientific papers in peer-reviewed journals that describe the outcome of the research activities described above.
- A review of techniques for effectively incorporating groundwater-surface water interactions in regional-scale models
- A model tool that simulates coupled groundwater, surface water and unsaturated zone processes in coastal low-lying water systems
- Model based scenarios of future fresh water availability under the influence of climate change and associated uncertainties in the study areas of the selected case studies
- Report describing adaptation strategies for the selected study areas
- Table of feasible adaptation strategies under different changing boundary conditions for various coastal low-lying water systems

D. Integration of general research questions with hotspot-specific questions

In present-day water management it is often unclear what the fresh-water demand in a particular area is and how much water is circulating in the surface water system. With these numbers unknown, future water demands and adaptation measures to climate change are impossible to evaluate. This study aims to investigate and quantify the volumes of water that are present in and are moving between the different compartments of the system, both by collecting field data and by modelling. The expected outcome is a better conceptual and quantitative understanding of the water and chloride balance at a local and regional scale that will allow for a more accurate assessment of the fresh water demand in a region. The aim is also to identify those regions that have sufficient fresh-water resources to become less dependent of external supply of fresh water.

Chloride concentrations in polder areas are highly-variable in both space and time. Saline seepage causes salinization of waterways which necessitates flushing with fresh water in order to ensure sufficient amounts of fresh water for irrigation. Salinity variations in surface waters also have important ecological effects. At present, our understanding of the temporal variations of the salinity of surface water is limited, thus hampering the optimization of the fresh water supply via the surface water network. This project aims to improve our understanding and predictive capabilities of the spatial and temporal varying chloride concentrations in ditches and canals.

The scientific work in this project will partly be done in the cases Haaglanden (Greenhouse Horticulture), Groene Ruggengraat (Groene Hart) and Zuidwestelijke Delta (Fruit cultivation Zuid-Beveland), thus achieving a good connection with specific hotspot-questions.

E. Societal deliverables and results

Fresh water is a scarce commodity during dry summers, and is expected to become even scarcer in the future. Before we can decide upon the best adaptation strategy, more must be known about the expected changes of fresh water availability. Insights from this project about future extremes in water scarcity will aid in selecting possible adaptation strategies in the regional water system, given existing uncertainties in the climate response. This project will strive to provide a sound scientific foundation for policy makers to decide on the proper adaptation strategy to sustain water-dependant functions in the future.

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Appendix 2-4

Project 2.2 (with work package 2)	
full title project :	Increasing the robustness and flexibility of fresh water lenses in saline seepage regions under climate stress
project leader:	Dr. ir. Gualbert Oude Essink
Type of research:	PhD
Duration:	2010 – 2014

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

Large parts of The Netherlands are at present situated several meters below mean sea level which results in the intrusion of sea water into the groundwater system and the upconing of saline groundwater from deep marine aquifers. The salinisation of Dutch coastal groundwater systems is mainly caused by two ongoing processes of anthropogenic origin for nearly a millennium. The first –drainage of peaty and clayey soil by digging channels and building dikes– is a slow and continuous process, leading to land subsidence by peat oxidation as well as compaction and shrinkage of clay. The greatest land subsidence of this kind occurred in the western and northern parts of the Netherlands. The second process – land reclamation – resulted in a relatively abrupt change in the land surface level, creating the well-known Dutch polders.

In many low-lying coastal provinces (Zeeland, Noord-Holland and Friesland), saline groundwater is often encountered at shallow depths (< 10-15 m). Precipitation surplus lead to the forming of rainwater lenses on top of saline groundwater. The thickness throughout the seasons may have major implications for these fresh water lenses. On top of the climate effects of rainwater lenses depends on factors like recharge, seepage flux, salinity, drainage characteristics. They vary in thickness from > 50 m in dune areas, 5 to 20 m in fossil sandy creeks to < 2 m in agricultural parcels in polder areas with prominent saline seepage. The fresh water availability for drinking water and agricultural purposes depends on these fresh groundwater lenses. Changes in precipitation and evaporation both in quantity and seasonal distribution as well as sea level rise will accelerate saline seepage in the lower lying areas. Moreover, the fresh water lenses will especially vulnerable during summer time, when both precipitation deficits and groundwater extractions for human and agricultural purposes are the largest. It is unclear whether or not these fresh groundwater lenses at different scales (dunes, sandy creeks, saline seepage areas) can cope with ongoing (sustainable) extraction rates under changing climate and socio-economical conditions. Water management in these low-lying areas should anticipate on these changes but the knowledge how to do is inadequate.

Aim

This research project aims to analyse what measurements are effective in mitigating the salinisation due to climate change, sea level rise and increasing need for fresh water. The aim is to increase the availability of fresh water by creating a robust and flexible buffering capacity of fresh water stored in those fresh water lenses.

This project 2.2 of WP-2 partially succeeds the Project Salinisation and freshening of phreatic groundwaters in the Province of Zeeland. Currently, in two other PhD-studies the presence and behaviour of shallow fresh groundwater in areas with saline seepage under present conditions is being studied and monitored at one site in the Province of Zeeland. Here, in this KfC project, four new activities on this fresh water lens research will be added: 1. to assess effects of climate change, sea level rise, land subsidence and socio-economical changes (land-use changes), 2. to up scale local knowledge of presence and dynamics of fresh water lenses and effects of future changes to the coastal area of The Netherlands, 3. to determine measures on a local or sub-regional scale to preserve or increase the fresh water lenses, 4. to make an assessment of the contribution of saline seepage to the nutrient (Nitrogen, Phosphorus) loading of surface waters.

Central research questions

1. How will future climate change affect fresh water lenses in brackish-saline conditions?
2. How can local-scale processes be up scaled to national/regional level and how can these processes be implemented in national/regional-scale models like Netherlands Hydrological modeling Instrument (NHI) or The Deltamodel?
3. What adaptation and/or mitigation strategies are best suited to ensure or increase the availability of sufficient fresh water, in view of the future climatic and socio-economical conditions?
4. Can enough fresh water be stored in sandy creeks to assure that water systems are independent from national fresh water supply?
5. What are the relative contributions of fresh groundwater discharge and saline seepage to nutrient fluxes towards surface water?

B. Approach and methodology

The research will be focussed on: a. extensive fieldwork to collect geophysical, hydrological and geohydrological information to better understand the behaviour of fresh water lenses to changing boundary conditions and b. the development of modelling tools, which can be used to predict the impact of sea level rise, climate change and measurements to adapt to and mitigate the salinisation. The field data will also be used to improve the reliability of the modelling tools, considering variable density groundwater flow, coupled salt transport and heat transport.

Precipitation, evapotranspiration, groundwater levels, groundwater outflow from drains and water courses and salinities and nutrient contents of groundwater and surface water will be measured in the study areas of the selected case studies. The focus point will to monitor the effects of changing boundary conditions related to climate change, sea level rise and mitigating measures. Based on these data conceptual models for coupled flow of soil moisture, groundwater (and surface water) will devise and elaborated further in conceptual and mathematical models. Collaboration with project 2.1 in building the modelling tools will be intensified. With these models scenarios for future climate, water level management will be studied. Also new drainage systems and groundwater recovery techniques will be optimized. Two study areas of field scale are proposed (depending on co-funding): one in a polder with vegetable/potato farming where a shallow fresh water lens is used for irrigation; one in a polder fruit tree farming (in the fruit cultivation area of Zuid-Beveland in the South-western Delta) where shallow groundwater is artificially being recharged under a water reservoir. In the latter study area, the focus is on the feasibility of storing fresh water in medium size fresh water lenses in sandy creeks, and its impact on ground- and surface water systems.

To address the research questions above, the following activities are envisaged:

1. Quantification of the effects of changing boundary conditions on fresh water lenses in brackish-saline environments under different hydrogeological conditions. Special attention is given to the shallow fresh water lenses in agriculture plots. The larger fresh water lenses in sandy creeks will be considered together with WP-4. Attention will also be paid to the nutrient concentrations in both the fresh water lenses and saline seepage
2. Estimating tipping points under climate change scenarios: to assess when and under what conditions fresh water lenses will disappear.
3. Quantification of present and future salt damage to crops (relation with WP-3).
4. Finding and testing feasible adaptation and mitigation strategies for sustaining fresh water supply in a saline environment on a local scale
5. Up scaling of effects of future changes of boundary conditions and effects of adaptation and mitigation strategies for sustaining fresh water supply to a regional scale.

C. Scientific deliverables and results

- Four scientific papers in peer-reviewed journals that describe the outcome of the research activities described above.
- A modelling tool to simulate variable density groundwater flow, coupled solute transport, heat transport and unsaturated zone processes
- Model based scenarios of future fresh water availability in shallow lenses and sandy creeks under the influence of climate change and associated measures

- Report describing adaptation strategies for the selected study areas

D. Integration of general research questions with hotspot-specific questions

This project will increase our knowledge of the behaviour of vulnerable fresh water resources at different scales in a brackish-saline environment, and their response to climate change. This knowledge is necessary to design no-regret adaptative and mitigative strategies for a robust and flexible self-sufficient fresh water supply under local and regional conditions. Moreover, the study answers the important question of how to continue to farm cultivated crops in a brackish-saline environment.

The core of the research is focussed on small fresh water lenses in the Zeeland, with interest for similar lenses in the Noord-Holland, Fryslan and the Water Board of Rijnland (all depending on co-funding). The sustainment of agriculture in these saline seepage areas is threatened by the combined adverse effects of climate change, sea level rise and land subsidence. Agriculture is now supported by small fresh water lenses, which are replenished during winters and used during the growing season. Expected extremes in the climate make the future existence of these lenses, and hence the agriculture it supports, uncertain. This research will also give preliminary insight into the role of saline seepage as a contributor to nutrient loading of surface waters (relation with WP-2 project 2.1).

In addition, a case study in Haaglanden (Greenhouse Horticulture) is also considered in collaboration with WP-4 (but depending on co-funding). The focus will be on the feasibility of storing fresh water under horticulture infrastructure in the subsurface, and its impact on ground- and surface water systems

E. Societal deliverables and results

- Better understanding of the hydrogeology of small, medium to large-scale fresh water lenses.
- Better understanding of the response to climate change of vulnerable fresh water resources in a saline environment.
- Knowledge about no-regret adaptation and mitigation strategies for local and regional self-sufficiency in the fresh water supply.
- Knowledge on how to continue to farm cultivated crops in a saline environment.

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Appendix 2-5

Project 3.1 (with work package 3)	
full title project :	Developing Climate Proof Dutch Salt Tolerance Response Functions for Crops
project leader:	Prof.Dr.Ir. S.E.A.T.M. van der Zee
type of research:	PhD
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Salt damage to crops can be due to reduced water availability due to osmotic effects, selective toxicity or deficiency due to unbalanced soil water composition, sodicity, and direct damage to leaves in case of sprinkling. For the assessment of the osmotic effects in the Netherlands, we still use a similar approach as Maas and Hoffman (1977 denoted MH77). It is recognized that the effect of salt damage depends on (nonexhaustively) plant species and crop type, soil type, salt type, and climate. However, the common approach such as MH77 over-simplifies the statistical assessment of the critical salinity that controls the salt damage function, similar to the drought damage using the Feddes function (Feddes et al., 1978). Consequently, the critical salinity and the slope of the MH-Feddes function varies if experimental conditions differ, and when other factors than salt concentration that affect crop yields are not kept constant. For this reason, crop response functions for salinity are not well-constrained. Since the primary effect of salinity on crop performance is often determined with hydroponic cultures, the translation of such data to field conditions can be quite complicated and further limit the applicability of the response functions. For the same reason data measured for e.g. Californian conditions (MH77) are inappropriate for Dutch conditions. Different types of plant species (e.g. mono- vs. dicotyls) deal with salt stress differently, and physiological behavior regarding the osmotic and the toxicity/deficiency effects that is specific for different plant species plays a role. For these reasons, the current database underlying salt damage assessments is flawed, the conceptual approach is biased (e.g. chronic vs periodical salt stress), and overly simplistic to deal with different conditions such as soil type and the timing of salinity levels in the Dutch climate. Aim of this project is to combine soil physical and plant physiological understanding to improve the translation of hydroponic culture data to field scale salt effects, to incorporate environmental aspects (e.g., periodicity of drought and salt stress; a combination of soil and climate/weather) with plant specific aspects (e.g., germination time and plant growth stages; vulnerability to salinity), into the assessment.

Central Questions are:

- How should we account for salt tolerance of plants that is useful for agri/horticulture practices?
- How can we relate laboratory assessments to the complexity of field scale conditions?
- How can we integrate spatiotemporal variability of weather, soil and hydrology in a risk/sustainability analysis?

B. Approach and methodology

The research involves the development of a conceptual model that relates the different factors that are important with regard to salt effects on wild plants and crops. Factors include (i) plant physiological, (ii) soil type, (iii) climate/weather, (iv) salt composition, and (v) management. The conceptual model is needed to synthesize the data obtained through a literature survey of Salt Response Functions (SRF) for different crops, and to serve as a template for deriving new SRF. The physiological factor concerns the species dependent sensitivities related with germination, seedling establishment, and growth stage, leaf burning depending on irrigation method, and specific effects of toxicity and deficiency in the NaCl-dominated Dutch brackish waters. The soil type, and physio-chemical properties such as hydraulic properties, chemical interactions and element cycling, affect the conversion of laboratory and hydroponic data towards field scale effects. This conversion is also affected by the climate/weather properties and their change during the 21st century. In particular, the periodicity of drought and salt stress and the intensity of these stresses during summers are of concern. This is a central aspect of the research, as for Dutch conditions, the combined drought and salt stress is seldom chronic but mostly limited to the summer. This is even the case for so called saline cultures, which may be resistant to salt, but may require low salt concentrations at germination in early spring. The management and the geohydrological conditions are of importance as they may influence the groundwater salinity, groundwater depth, and leaching efficiency of salts in the wetter fall-spring period. The conceptual approach is twofold: the development of SRF and the integration of SRF in ecohydrological modeling, to enable projections of drought and salt stress under changing conditions. The SRF development involves hydroponic experiments that reveal salt effects at different stages and different duration, as well as pot experiments for selected soils. Using the modeling framework SWAP-ORCHESTRA (Kroes & van Dam, 2003, Meeussen, 2004, De Jong van Lier et al., 2008), the SRF are translated to conditions of field situations. This is an essential step in this project, because it concerns of more than just correcting functions derived from hydroponic studies towards those that account for a limited water filled pore space as in soils. As soon as the soil system comes into perspective, also the origin of salts becomes important, as brackish groundwater leads to completely different conditions than brackish water sprinkler irrigation. The type of soil affects the buffering against changes (of salinity, for instance), the distance over which capillary rise of saline water from the groundwater may occur, and the sensitivity to drought. Hence, besides the primary correction from hydroponic to soil based conditions, the SRF need to comprise implicitly also the ambient conditions and management practice, which cause drought and salt effects to be location specific. From climate scenarios from other projects, weather time series will be derived (rainfall intensity and frequency, evapotranspiration demand), with which future drought and salinity risk assessments become feasible. For practical applications, SRF can never be expressed in terms of computer models. Instead, they should be robust and simple, and input data should be well known or routinely measurable. For this reason the long-term risk of crop yield depressions due to drought and salinity is investigated for the Dutch climate, crops, soil types, and geohydrological conditions in an ecohydrological framework (R, Shah et al., 2010, Suweis et al., 2010, van der Zee et al., 2009, Vervoort and van der Zee, 2008, Rodriguez-Iturbe and Porporato, 2004). With regard to geohydrological conditions, a good link with workpackage 2 is required, with regard to crops and management, the stakeholders need to be intensively consulted to investigate boundary conditions and options for changing those. Results will be translated in WP6 into tables that can be used by both the authorities and the farming community.

C. Scientific deliverables and results

- methodology for developing salt tolerance functions (SRF) that integrates plant physiological, hydrological, soil, management and climate/weather aspects
- parameterization of SRF for different combinations of plant, soil, and weather properties
- ecohydrological modeling of drought and salt stress to crops: a long term, dynamic statistical risk assessment
- framework for assessing salt stress implications for crops and natural vegetations of projects 3.2 and 3.3 of WP3
- SRF in the form of tables (and excel sheets)

D. Integration of general research questions with hotspot-specific questions

Interest in the relationship between water quality and ecology was mentioned by HSOV and in particular the question of the effects of dry years and salt concentrations and whether fresh water lenses will continue to function well (HSRR, HSWZ) are integral parts of these projects (effects of drought and salinity on land use, and management options). Effects on nature, species and restoration after temporal salinity can only be assessed if SRF are known well enough. Both for nature (salt as a filter for unpopular species) and (as a boundary condition) for agriculture, if continued in the Schiphol area, the salt – plant responses need to be known. The availability of water and its quality, in relation with agriculture/horticulture/saline cultures/nature demands, and the water allocation conditions derived from that, need to account for the salinity that plants can or can not deal with (HSWZ, HSZD, HSRS). In this respect, alternative saline cultures have been mentioned explicitly by HSRS, but in particular with regard to developing nature in this mainport, management costs can be positively affected by salt filtering of species.

E. Societal deliverables and results

At this moment, the Dutch authorities compensate farmers if salt damage occurs. All parties benefit from improved Salt Response Functions SRF: compensations are given to those really needing it, fresh water can be directed more efficiently to those requiring it. With better SRF, drought and salt damage can be better anticipated and on this basis flushing of surface water can be optimized. Hence, we can improve water use efficiency, but at the same time, farmers are better able to judge the need for interventions in view of salinity hazards and decide whether their planned crops can be grown sustainably in view of costs for fresh water.
In a broader context, the awareness of salinity hazards in (irrigated) agriculture in Southern Europe, and many other arid and semi-arid countries is even more urgent, and understanding developed in this project will be of profound

interest to stakeholders abroad, where conditions differ from those of California (Maas Hoffman, 1977).

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Appendix 2-6

Project 3.2 (with work package 3)	
full title project :	Adaptation to dry and saline conditions by crop cultivation exploiting brackish water and saving fresh water
project leader:	Prof. Dr. J. Rozema
type of research:	PhD
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

Gradual and irreversible salinization in the Dutch delta due to global climate warming threatens conventional agriculture. Measures to combat salinization require vast amounts of fresh water at high costs. Fresh water from lake IJsselmeer and Markermeer is used to flush salinizing polders and to suppress upward seepage of brackish water. Recently developed national (National Waterplan 2009) and regional (Waterbeheersplan 2010-2015 HHNK, 2009) policy, aims at saving fresh water during periods with increased drought and salinity.
This project evaluates the possibilities of agricultural exploitation of brackish (and saline) water by cultivation of suitable crops, without yield and quality losses. As a result, vast amounts of fresh water will be saved, to be used for other purposes.

Aims

1.*Adaptation* to salinization through an integrated study of crop cultivation *exploiting* brackish water, rather than considering salinity as an adverse factor for conventional agriculture. thereby increasing the availability of fresh water for other purposes (for maintenance of the ground and surface water levels in large areas of the country; for drinking water, industrial use, for conventional fresh water horti- and agriculture)
3. To cultivate various crops under fresh, brackish and saline conditions under field and hydroponic conditions
4. To quantitatively (yield) and qualitatively assess and compare the response of various crops cultivated with fresh, brackish and saline ground and surface water. These salinity- crop response deliverables are developed in cooperation with projects PhD 3.1&2 of (this) WP3.

Central Research questions

The response of crops to brackish and saline conditions will be obtained both in field conditions and with hydroponic cultures and based on a combination of these results a crop may be classified as suitable for cultivation under brackish and saline conditions. This classification will also be based on the derived new SRF in the complimentary project in this WP. In some cases the response to salinity found under field conditions is similar to that obtained with hydroponic culture but often discrepancies occur which may relate to irrigation water composition, soil type and weather conditions. For this reason, crop response functions for salinity can very significantly. Since the effect of salinity on crop performance is often determined with hydroponic cultures, the translation of such data to field conditions can be quite complicated.
More generally classification of salt tolerance of crops is based on threshold and slope of the response curve as described by Maas and Hoffman (1977), based on US climate and soil conditions. This classification systems also neglects that seasonal changes of salinity, precipitation and temperature affect crop performance. If we wish to assess which crops are suitable to be cultivated with brackish water, the central questions are:

- How can we conduct and translate experimental research for laboratory and hydroponic cultures to be relevant for field conditions, in view of salinity, precipitation and temperature variability?
- How do ‘saline’ cultures respond to transient exposure to salt, both with regard to duration and with timing (e.g. seedling phase) of that exposure?
- How can saline agriculture as well as screening of the viability of particular cultures be protocolled towards broadly accepted standards?

B. Approach and methodology

The aim of this project is to combine soil physical and plant physiological understanding to improve the translation of hydroponic culture data to field scale salinity effects. Conditions of hydroponic cultures are kept constant or vary in a controlled way.
In the Noord-Holland field project on the Wadden island of Texel crops will be drip-irrigated with Wadden Sea and brackish water in sandy soil. In Friesland (Westergo region) crops will be drip- irrigated with brackish (ground) water in clayey soil.
Crops to be tested are sugarbeet, and sea beet, Salicornia europaea, Aster tripolium (all dicots); wheat, barley and corn, all monocotyledons.
Through the ongoing or co-financed projects it is feasible, with moderate costs, to establish a significant field based effort, where our intent is to ascertain sufficiently generic understanding and quantification to be relevant for other areas (e.g. with other soils, geo-hydrological conditions, and possibly climates).

The cultivation of crops with brackish water under field conditions builds on the experience acquired during the 2006-2009 period as part of the BSIK Zilte Landbouw project in Noord-Holland. Field conditions in this project will be monitored to allow a comparison with conditions of the hydroponic culture and comprise a.o. salinity of the irrigation water and of the rooting zone, flux of the drip irrigation system, temperature, rainfall intensity and frequency.
In the field experiments the effect of a varying germination time of the seed and varying plant growth stages in response to the brackish irrigation water will be analyzed as well as the dependence of crop performance on periodicity of drought and salt stress. Crop parameters to be measured are described in detail in de Vos and Rozema (2009).
By participation in ongoing projects (see D) this agronomic research component is extended towards both environmental and economic sustainability (e.g. profitability).

C. Scientific deliverables and results

- Salt responses of various ‘saline’ crops to increasing salinity under various soil and weather conditions
- These responses will be co-developed/combined with those developed by PhD 3.1 and 3.3 (this WP) and will be used as input for ecohydrological modeling (conducted mainly by PhD 3.1).
- Assessment of yield, quality and market value of crops cultivated under varying salinities
- Classification of the suitability of various crops for brackish and saline cultivation based on field tests and after application of the new SRF
- Manuals and protocols describing the practice of brackish and saline cultivation of crops

D. Integration of general research questions with hotspot-specific questions

Recent evaluations (National waterplan, 2009, Ministerie Verkeer en Waterstaat; Waterbeheersplan, Hoog-heemraadschap Hollands Noorderkwartier 2009) point towards increasing problems of drought (frequency, duration, intensity) and salinization in the coastal regions. For the period 2010-2015 the national and regional policy will be to reduce use (and costs) of fresh water for flushing saline surface waters. The present project aims at exploiting vast amounts of brackish water for agriculture while maintaining high, profitable yields. The current project is closely linked with successful innovative projects funded by the Provinces of Noord-Holland and Friesland: “Gemengd Zilt Aqua-Agrarisch Bedrijf”, “Zilte Landbouw Texel”, the icon project for the Wadden area, including Noord-Holland, Friesland en Groningen and the project “Standaardisatie Zilte Teelten” (‘Standardizing Saline Cultures’) financed by the Ministery of LNV. In this project, companies cultivating saline crops from South-West Netherlands and the Wadden region cooperate with knowledge institutes (VU and WUR) and the Organisation for Agriculture in Saline Environments (OASE)**.** In addition, Rozema is involved in the project “Zilte teelten op de kaart” coordinated by LTO Noord, an organisation of agricultural companies of nine Dutch provinces north of the river Meuse. This project aims at further developing saline and brackish agricultural economy in the Netherlands.
Hotspots involved with KvK theme 2 do not specifically address saline and brackish cultivations, but certainly aim at a climateproof agriculture, by reducing the unnecessary use of fresh water, so that more is available in dry and saline periods. The current project undoubtedly contributes to saving vast amounts of fresh water, to be used for other purposes such as. drinking water, industrial processes, fresh water agriculture and maintenance of the water table of IJsselmeer and Markermeer and that of the adjacent rural and urban areas.

E. Societal deliverables and results

The project indicates the possibilities of *adaptation* of increased salinisation of Dutch coastal regions as a result of sealevel rise, increased drought due to a warming climate, rather than (expensive) *combating* salinisation. More in particular:
1.The project explores the possibilities of agricultural use of brackish and saline water,
2. It is projected that vast amounts of brackish water can be used for the cultivation of crops, while yield and crop quality do not or only hardly decrease.
3. Use of brackish water for agriculture will save high amounts of fresh water, to be used as drinking water, industrial process water, for specific agricultural and horticultural practices and maintenance of a high water table of of IJsselmeer and Markermeer and in rural and urban areas in the Netherlands.
4. Flushing with fresh water of polders to suppress increasing salinity due to seepage of brackish ground water can be significantly reduced. This will save vast amounts of fresh water and enormous maintenance costs in the water economy of the water boards.

Salinity of ground and surface water varies markedly from brackish conditions to seawater salinity, which requires the evaluation of crops with varying salt tolerances. Brackish water, though, prevails in the Dutch delta and seawater salinity at inland locations is rare. Where nature values prevail and appear to be linked with brackish or saline ground water, a different scientific approach is followed as described in project 3.3 in WP3.

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Appendix 2-7

Project 3.3 (with work package 3)	
full title project :	Predicting effects of changing salinity on inland natural systems on the Dutch coastal plain
project leader:	Prof. Dr. Ir. S.E.A.T.M. van der Zee
type of research:	PhD
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

There is consensus that climate change will cause more distinct seasonal differences in drought, rainfall, and temperature in the Netherlands. Summer droughts are expected to occur more often and last longer, and rainfall is expected to be concentrated in more intense showers (Beniston et al. 2007, Van den Hurk et al. 2007).

As a result, salinity pressure will very likely increase periodically in many parts of the Dutch coastal plain. In combination with ongoing sea level rise and soil subsidence, this will cause shifts of current fresh-saline gradients in space and time. In the longer term, current freshwater-dependent ecosystems are likely to experience salinity stress or may turn into brackish systems. Attempts to restore and redevelop nature aiming at particular vegetation types will also be affected by salinization, resulting in different outcomes than expected (Harris et al. 2006). While inland brackish natural areas have become rare in the Netherlands due to major sea defense works, increasing salinity may potentially put high-valued freshwater-dependent communities at stake.

Past studies referring to the Dutch situation (e.g., Roelofs 1991, Ertsen et al. 1998) generally have a qualitative and correlative character or focus on specific ions rather than total salinity. Moreover, temporal variability is usually not adequately taken into account. Finally, while surface runoff is generally disregarded and salinization of the root zone by upward seepage is difficult to quantify, both processes are important for establishing adequate hydrological and chemical balances for the root zone of (semi-)terrestrial systems.

Due to limited knowledge of the exact relationships between salt-related abiotic conditions and biodiversity (in particular plant community composition), it is at present difficult to adequately predict salinity-driven changes and damage to ecosystems (Nielsen & Brock 2009).

Aim

To quantify relationships between the spatiotemporal dynamics of drought/salinity and vegetation in terms of species, plant traits and species composition.

Central research questions

1. Theoretical basis: what are the best variables or properties to quantify salinity responses and damage thresholds?
2. Time series analysis and descriptive field studies: how do plant and vegetation-related variables correlate with spatiotemporal salinity patterns?
3. Mesocosm experiments on plant communities: what are the short-term dose-effect relationships between salinity and vegetation response parameters?
4. Model building and prediction: how can the empirical outcomes be translated into variables for ecological models and how may Dutch natural areas respond to future salinity-related changes?

B. Approach and methodology

Theoretical basis (research question 1)
The variables (both plant and soil variables) that are most appropriate for quantification of the relationship between salinity and vegetation response (e.g. damage thresholds) will be assessed. This relationship can be described at the level of species (presence/absence) or vegetation types (community composition, probability of occurrence of given vegetation types). Another approach is to link salinity to the indicator values of Ellenberg et al. (1991) or of Runhaar et al. (2004) (Ertsen et al. 1998) or to functional plant traits such as leaf Na-content of leaf K-content (TRY database, Cornelissen et al. 2003). An advantage of the latter approach is that it is less susceptible to apparent correlations and selective sampling procedures. As a result, the relationships will be less biased and more robust, and will allow for extrapolations (Witte et al. 2004, McGill et al. 2006). Choices to be made regarding the variables that will be related to each other (e.g. vegetation functional properties with salt concentrations or loads) will obviously have practical implications for the remaining parts of the project. The options mentioned will be addressed on the basis of a literature review and re-analysis of available data sets. The three PhD students in this work package will closely cooperate to select the best suited variable or set of variables.

Time series analysis (research question 2)
Time series data can be used to relate abiotic variables to biotic variables. One option is to relate Alterra's Dutch Vegetation Database to biogeochemical data series (cf. Schaminée et al. 2007). This database contains about 500,000 vegetation samples (releves) dating from the 1920s onwards, a period characterized by large-scale transitions from brackish to fresh conditions in several parts of the Netherlands. This analysis may help identifying relationships between vegetation response on the one hand and the selected salinity variables on the other.

To strengthen and fill possible gaps in the outcome of the time series analysis, we envisage gradient-dependent monitoring to empirically assess how biotic variables (plant fitness, traits, and community composition) co-vary along salinity gradients in selected Dutch natural areas.

Experimental work (research question 3)
Studying correlative relationships may lead to wrong interpretations in the case of unrecognized cross-correlations or biased sampling. In this project, experimental work will help to minimize this risk. Experiments are needed to define short-term cause and effect relationships between salinity and vegetation response parameters. Part of the experiments will be carried out in a climate room, greenhouse, experimental garden or in the field, respectively. In any case, we envisage using mesocosms plus perhaps individual species as the experimental units. For practical reasons, we will focus on relevant and important (e.g. Natura 2000) communities (see WP6). The biotic response to a realistic concentration gradient and its temporal dynamics will also be studied in the experiments. Possible response variables to be considered include functional characteristics such as biomass, plant fitness and nutrient status, germination and seedling establishment rates, selected functional plant traits, mycorrhizal colonization, and soil microbial activity (Antheunisse et al. 2007, Geurts et al. 2009).

The correlative fieldwork and the experimental work can be elaborated upon in cooperation with WP6 and the two other PhD students of this work package.

Modelling (research question 4)
The use of experiments will allow for the development of ecological predictions on short-term plant response to salinity change. The outcomes of the experiments and the other mentioned project elements will be combined in the development of a model (conceptual and possibly mathematical/statistical) aimed at expressing how changes in salinity pressure will affect natural systems.

C. Scientific deliverables and results

We expect that at least four scientific papers will result from this project, linked to the four central research questions:

1. A theoretical study on quantification of vegetation responses to salinity changes, including assessment of damage thresholds.
2. An overview of changes in plant species composition of natural areas in previously brackish areas of the Netherlands since the first half of the 20th century.
3. Empirical relations of the responses of selected vegetation types to salinity changes and threshold exceedance.

4. A description and prediction of vegetation responses to salinity changes and threshold exceedance.

D. Integration of general research questions with hotspot-specific questions

Availability of sufficient high quality freshwater to natural areas as well as for other functions during periods of drought is a major and growing concern to hotspot regions on the Dutch coastal plain (e.g. Ondiepe wateren and veenweiden, Haaglanden, Rotterdam, Zuidwestelijke Delta, Schiphol). In view of climate change, the Dutch National Water Plan (2009) aims at regional self-sufficiency with respect to freshwater supply. How scarce freshwater supplies should be distributed is an important question for many hotspot regions and partners. This is important due to biodiversity targets and European regulations (Water Framework Directive, Birds and Habitats Directive). Therefore, for hotspot regions it is important to know which natural areas and which natural communities are present and to what degree they are sensitive to saline water. This knowledge will help them in managing and restoring natural areas and (re)formulating biodiversity targets.

E. Societal deliverables and results

Societal relevance

At present, options to adequately predict the consequences of (periodically) changing salinity levels on inland Natura 2000 sites and other natural areas in the Netherlands are extremely limited. However, there is a clear need for knowledge on this point, since several EU directives impose upon the Dutch authorities the need to protect characteristic communities of their natural areas as well as the ecological and chemical quality of their hydrological infrastructure.
The developed model will allow predictions of how Dutch natural areas will respond to future salinity-related changes.

Discharge of the Rhine and other main rivers is expected to decrease in summers. This will increase the salinity of these rivers. In addition, decreasing river discharges will significantly enhance upstream intrusion of seawater. This will limit the possibilities for the traditional supply of surface water from the main rivers (e.g. as near Krimpen a/d IJssel) to freshwater-dependent natural areas during periods of drought. Likewise, as addressed in work package 2, upward seepage of saline groundwater will cause increasing salinity pressure to the Dutch coastal plain. This may cause local extinction of sensitive freshwater-dependent species.
Several peaty lowland or meadowland areas (e.g. Reeuwijkse, Nieuwkoopse, Vinkeveense, Ankeveense Plassen, het Hol, and Ilperveld) are sensitive to changes in salinity of supplied water from outside. However, just how sensitive the natural communities in these areas to increased salt levels is not sufficiently clear.

Applied aspects
This project aims at identifying scientifically sound damage thresholds for key natural units and priority areas. Moreover, the project will deliver a model tool allowing managers of water resources and natural areas as well as government bodies to better anticipate future salinity trends and fluctuations and to optimally weigh management options.

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Appendix 2-8

Project 4.1 (with work package 4)	
full title project :	Water storage for self-sufficient regional water supply
project leader:	Prof. dr. P.J. Stuyfzand
type of research:	applied scientific, 1 PhD
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

In the Netherlands, climate change may lead to increased peak flows and flood risks during winter in addition to more pronounced low flows during summer [9]. Consequently, it is expected that in surface water systems the concentrations of total suspended solids and pathogens will increase in winter, and those of most other pollutants in summer [10,11]. As a result, many KvK hotspots in the Netherlands may experience reduced water availability and impaired water quality for domestic, agricultural, and industrial purposes during summer and peak demand times. Furthermore, in deltaic regions these problems can be further exacerbated by the threat of marine salinization of water resources during low flow periods [12,15]. In order to prevent regional water shortages, the storage of rainwater, surface water, treated sewage or de-mineralized water in aquifers and/or surface reservoirs constitutes an important adaptation measure. The objective is to store excess water of suitable quality during hydrological peaks for later use during periods of water shortage or peak demands. Innovative and efficient methods of storage will help alleviate regional water availability pressures and ensure delivery of sufficient, high quality water for agriculture, horticulture, industry and municipal drinking water.

Two hotspot areas have been identified where additional local and regional storage is in high demand: the “Zuidwestelijke Delta” and “Haaglanden”. Both regions are home to intensive horticulture and agriculture and are experiencing water shortages during times of peak demand and water quality problems in summer when water supplies are more saline. Two types of storage will be considered: LSR-ASR, a new technology composed of a Leaky Storage Reservoir combined with phreatic Aquifer Storage and Recovery via the reservoir (hotspot Zuidwestelijke Delta); and ASR, a relatively proven technology of aquifer storage and recovery via wells that are used for both injection and recovery (hotspot Haaglanden).

Proper water storage is a complex procedure, particularly when native groundwater is brackish and infiltration water is eutrophic or demineralized. Expected difficulties with LSR-ASR include algal blooms, deposition of clogging muds, hydrological impacts on local surroundings, and negative quality changes due to interactions with the aquifer and muddy sediments. Utilizing ASR wells presents numerous hydrochemical challenges [7, 8]. Firstly, infiltration water must be of sufficiently high quality, or otherwise selective intake and/or pre-treatment will be necessary [5]. Furthermore, chemical reactions with the aquifer can lead to Fe, Mn, NH_4 and As concentrations above drinking water standards [1]. The loss of infiltration water (or “bubble drift”) can also occur in aquifer systems that become increasingly saline or are used for other purposes [5]. Finally, aquifer deterioration can occur due to accumulation of pollutants, clay mobilization, or leaching [6].

Aim

The goal is (1) to evaluate and optimize the performance of LSR-ASR and ASR in a brackish to saline groundwater environment, in terms of water quality, storage capacity and recovery efficiency; (2) to evaluate and minimize their adverse environmental effects; and (3) to evaluate the feasibility of their integration with brackish water reverse osmosis to store and recover desalinized water.

Research questions

The following main research questions will be analyzed in the context of the hydrogeological and hydrogeochemical setting of hotspots Zuidwestelijke Delta and Haaglanden:

1. What are the hydrological and chemical effects of LSR-ASR systems during the filling, storage and recovery stage, how can their hydrological effects be mitigated, and how can salinization, eutrophication and iron flocculation during abstraction from the reservoir be prevented?
2. How can a LSR-ASR system be optimized in order to also form a buffer against extreme annual anomalies in either supply or demand?
3. How can ASR systems be improved so as to maintain or enhance favorable soil-water interactions (like denitrification and biodegradation of pollutants) while minimizing the negative interactions with the local environment (such as arsenic mobilization)?
4. How can ASR fresh water lenses be monitored and prevented from drifting away due to lateral groundwater flow or buoyancy?
5. How can the suspended solids content of turbid surface or rain water during short peak flows be reduced rapidly and at low cost so that this water can be infiltrated directly without risks of clogging?
6. How can ASR systems be combined with brackish water reverse osmosis to store and recover desalinized water? (See companion project nr. 9)

B. Approach and methodology

Disclaimer: The methodology described below only gives an outline of the research possibilities. The final research project will depend on the project's budget, which is not defined yet as the amount of co-financing generated by the different stakeholders is still unclear.

Comment [OE1]: I agree, but does this disclamer not be placed in every WP, or better, in the main text?

The research will be comprised of 2 pilot studies in the Netherlands, in a brackish-saline groundwater environment:

1. A LSR-ASR system in a Holocene, sandy creek infill in Zeeland (hotspot Zuidwestelijke Delta); and
2. A selection of 1-3 ASR wells in the Westland greenhouse district in the province of South Holland (hotspot Haaglanden).

The research methodology for both studies will involve an extensive field site characterization, intensive monitoring of hydrological and hydrochemical parameters, laboratory column studies, and modeling simulations to quantify the processes involved, to evaluate and analyze various climate and hydrogeochemical scenarios. This will result in an in-depth understanding of the mechanisms involved in both systems.

The field site characterization will map the sedimentary hydrogeological units and their geochemical composition using drilling, core penetration, and geophysical and laboratory techniques. Characterization and mapping of native groundwater quality will be accomplished by utilizing standard observation wells, mini-screened wells, pumping wells and by analyzing pore fluids from aquitard cores.

Intensive monitoring of hydrological and hydrochemical parameters will proceed using a variety of techniques. Water quantity, pressure, temperature, and specific electrical conductivity will be monitored for 1-2 years using CTD Divers. Vertical temperature logs in the surface reservoir and observation wells will be taken and water quality parameters (environmental tracers, major constituents, trace elements and selected organic micropollutants) will be routinely measured. This monitoring program will be reinforced by column studies in the laboratory, to elucidate the kinetics of the water-sediment interactions in relation to water temperature, pH and/or redox conditions.

Finally, using knowledge from the monitoring program and column studies, modeling of the system will be conducted and scenario studies carried out on results. The modeling will be performed utilizing a reactive transport code such as PHREEQC-2 or PHT3D and, where feasible, an analytical approach will also be undertaken.

C. Scientific deliverables and results

The proposed project will provide the comprehensive knowledge necessary to answer the research questions outlined, with intensive field measurements forming the basis of this knowledge. As it is a new concept, data from LSR-ASR systems have not yet been reported. Although various small-scale ASR systems are already operational in the region, no monitoring has been carried out and lots of problems have been reported [2] due to well clogging, aquifer pollution, the admixing of brackish groundwater and undesired water quality changes due to interaction with very reactive aquifers.

This research offers excellent opportunities to quantify the kinetics of (bio)chemical reactions and the complex surface/groundwater interactions necessary for proper evaluation. Research will address the need to obtain degradation constants for oxidants and specific micropollutants in real systems with combined seasonal and annual fluctuations in temperature, clogging and redox zonation [4,13,14], as opposed to utilizing biased data from rapid and overly specific laboratory testing [8]. Furthermore, as multi-tracing methods will be applied to characterize and follow infiltration water, the effectiveness of individual tracers in specific environments can be analyzed. The unconsolidated and fine-grained nature of the sediments involved will allow for a detailed and intricate monitoring set-up, providing a high quality data set. Finally, a reactive transport model will be delivered for each system, which can be utilized to predict water quality and quantity issues for similar systems under various scenarios.

The research will be published in the form of a PhD thesis and four peer-reviewed articles in scientific journals. A management summary of the results, including all relevant implications for regional or local water supply, will be published in 2 progress and 1 final report.

D. Integration of general research questions with hotspot-specific questions

By investigating the challenges and potential of storing fresh water in LSR-ASR and ASR systems, the research assists in providing an additional source of secure and efficient water to the hotspots in question. Through understanding of the hydrological and chemical processes involved with both storage methods, the practicality and efficiency of both methods can be evaluated. Results from the research will optimize the systems so that the maximum amount of high quality water can be obtained.

E. Societal deliverables and results

An effective regional water supply is integral to the long-term environmental and economic sustainability of the involved hotspots “Zuidwestelijke Delta” and “Haaglanden”. Given current pressures on water resources in both areas and the threat of additional pressures from effects of climate change, this research will assist in making the hotspots more self-sufficient and resilient. This is important in ensuring a secure supply of water for horticulture, drinking water, and industrial and agricultural purposes. As the research is conducted in brackish-saline water environments, the results, tools and knowledge generated can be extrapolated to other areas of the Netherlands requiring additional methods of water storage as well as to coastal and deltaic regions worldwide.

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Appendix 2-9

Project 4.2 (with work package 4)	
full title project :	Water technology for self-sufficient, regional water systems
project leader:	Ir . R.J.M. Creusen (TNO)
Type of research:	desk and field studies
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

The regional water system in the western part of the Netherlands depends on fresh water from the main rivers (Rhine/Meuse) in periods of drought. However, due to the effects of climate change, brackish/saline intake water from the Rhine-Meuse basin may be more common due to periods of low river discharges and salinity pressures from rising sea levels [11, 12]. In this low-lying region, the availability and quality of fresh water is of major importance particularly for the greenhouse and industrial sectors.

One adaptation strategy to ensure future availability of enough fresh water is to improve the regional self-sufficiency by optimizing the use of alternative water sources and making these sources suitable, through water technology, as fresh water sources for major users like agriculture, the greenhouse and industrial sectors. Alternative regional water resources can be eutrophic, brackish surface water or groundwater, and polluted waters like rain water, stormwater runoff, greenhouse drain water and treated sewage effluent. To optimally utilize these alternative resources, (innovative) water technologies are required for proper removal of suspended solids, dissolved salt and contaminants. Matching of demand and supply may also require storage (see project 8). Transport and distribution infrastructure is needed to bring collected and pretreated water to the storage location and transport the water from storage to end users. In case of agriculture, this may cause extra challenges, as salt sensitive crops can change position.
As an alternative, (small scale movable) units can be utilized, using water from local surface water as a source. Furthermore, desalination processes generate brine as a by-product and require environmentally accepted solutions for disposal [9,10]. This because the discharge of brine can contain high concentrations of nutrients, salt and/or pollutants.

Aim

Our aim is to select, develop and optimize various water technologies in order to contribute to a more self-sufficient regional water system for fresh water supply, particularly in low-lying regions in the Netherlands where salinization of surface water and groundwater is occurring or is projected to increase due to climate change. The water technology is to be developed for the above mentioned alternative regional water resources which in the current situation are not suitable for use as fresh water source for greenhouses and industry or use as regional surface water. Storage, transport and distribution concepts will be developed. Moreover, various techniques (solid salts, solutions) to solve the brine problem are studied.

Research questions

This research will address the following questions:

1. What are the major alternative water sources available for regional use and are they of suitable quality?
2. What is the best available technology to make alternative water sources suitable for use in the greenhouse sector, for industrial process water, agricultural use or flushing the regional surface water network? What are the pros and cons of these technologies, in terms of water quality, costs, energy consumption, environmental impact, regulations etc.?
3. If wastewater is used, can additional benefits, e.g. phosphorous reuse and energy production be combined with the required treatment systems?
4. Are innovative desalination techniques (like Memstill technology or Forward Osmosis) feasible as compared

to more common desalination techniques (reverse osmosis and evaporation)?

5. Can membrane distillation-crystallization technology be applied to change membrane concentrate into solid waste (no liquid discharge), and can this be demonstrated on a laboratory scale (2 L/h)?
6. Can we dispose the brine in an environmentally acceptable manner (eg. by deep well injection into a deeper more saline aquifer, or by creating solid salt residues)?
7. What are effective distribution systems to feed storage systems and to provide fresh water to (moving) users?

B. Approach and methodology

Disclaimer: The methodology described below only gives an outline of the research possibilities. The final research project will depend on the project's budget, which is not defined yet as the amount of co-financing generated by the different stakeholders is still unclear.

First, in selected regions (hotspots Haaglanden and/or SW Delta) an inventory of the most appropriate alternative regional water sources will be made and analyzed. This will consist of a desk study on water quantity and quality, and localization of availability and demand points. This desk study will build upon local knowledge of the stakeholders.

Secondly, several water technology aspects are analysed in detail which make the water sources suitable for fresh water use. They include: desalination of brackish groundwater; use and treatment of the effluent from waste water treatment plants, including phosphorous recovery and energy production; re-use of wastewater; use and treatment of rainwater; methods for water transport and storage (in combination with project 8). The following specific steps are foreseen:

- Literature search into the technological opportunities (desk study and demonstration) to make the various sources of water suitable for agriculture, industry and regional surface water. Not only commercially available technologies will be addressed, but also innovative technologies like Memstill (membrane distillation) where waste heat can be used to make fresh water.
- Demonstration of Memstill technology [4,5,6], in which technology problems, like how to handle sustainable energy supply, fouling and scaling [7], are addressed.
- Feasibility study of the investigated technologies in terms of water quality, costs, energy consumption, environmental impact and regulations.

Thirdly, there is the question how to solve the brine problem that is inevitably associated with application of desalination techniques [9,10]. The following specific activities are foreseen, in order:

- An inventory will be made of the current projects on this theme in the province of South Holland, in terms of geographical distribution, water source, performance, technological issues, etc.
- The hydrological and hydrochemical impacts of brine injection into confined saline aquifers will be studied in a pilot study in the field in the hotspot Haaglanden.
- The following practical questions will be answered regarding the combined concentration-crystallization process to produce a solid end product which may be reused for industrial applications (the "no-waste" concept of TNO):
  - Can membrane distillation and crystallization be integrated in the same module?
  - How to prevent plugging of the module by crystallization on the membrane due to concentration polarization and/or temperature polarization?

C. Scientific deliverables and results

1. A decision instrument for selecting the best purification technology of a given set of raw water qualities, under conditions of quantity, availability (periodical, perennial), costs and environmental side effects.
2. Demonstration of innovative water treatment technology, in casu Memstill desalination, on a small pilot scale.
3. Demonstration of innovative brine treatment technology on laboratory scale (concentration and crystallization processes)
4. Field evidence of the hydrological and hydrochemical impacts of brine injection into a saline aquifer, with

focus on injection well clogging and quality changes of the brine in the aquifer.

The research will result in 2-3 peer-reviewed scientific articles and a scientific report.

D. Integration of general research questions with hotspot-specific questions

The research theme of this project, using water technology to improve regional self-sufficient fresh water supply, is relevant to all the hotspots confronted with the impacts of salinization: Zuidwestelijke Delta, Haaglanden, Rotterdam, Schiphol (region) and Waddenzee. The Zuidwestelijke Delta and Haaglanden hotspots particularly have expressed their keen interest in research to enlarge the regional self sufficiency of water supply. Research on water technologies will provide innovative, new methods to help achieve this goal.

E. Societal deliverables and results

The research project will lead to innovative and practical knowledge and technological concepts which will contribute to more self sufficiency of fresh water supply on regional and local scale, thus constituting a robust adaptation measure to climate change. In a salinizing environment such as the Zuidwestelijke Netherlands, this knowledge is indispensable.
The results of the study will be used to advise both the regional and national authorities which have to make choices about adaptation strategies.

The provision of technology development for more regional self-sufficient water supply in saline environments is important for all deltaic and coastal regions. The knowledge and concepts generated in this research can be utilized to help develop alternative water supply in similar regions worldwide. In addition, newly-developed or optimized processes for treatment and disposal of desalination brine with minimal environmental effects are relevant for all countries that operate desalination plants (Middle Eastern countries, Spain, Australia). Addressing this environmental issue could open up new possibilities for the wider implementation of desalination plants globally.

WORD COUNT: 1339

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Appendix 2-10

Project 5.1 (with work package 5)	
full title project :	Adaptation under uncertainty: resilience as a strategy for climate proofing fresh-water dependent networks of protected areas ("groene ruggengraat")
project leader:	Dr. Jeroen P. van der Sluijs
type of research:	Other (junior researcher)
duration:	four years (part time)

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

The "Green Backbone" (Groene Ruggengraat) that is currently being realized in the West of the Netherlands will connect a range of wetlands to form a robust ecological network of protected areas. These wetlands derive much of their ecological value, biodiversity and attractiveness from the abundance of fresh water of sufficient quality. Climate change may bring disturbing stresses such as periods of extreme droughts, periods of extreme rainfall, salt water intrusion, floods and invasive species. Through these stresses, climate changes poses major challenges to the long term viability of the Green Backbone and may force it into regime shifts towards undesired system states. These stresses come on top of non-climate related stresses such as soil subsidence, drying out, fragmentation, pollution, and a multitude of competing land use claims and functions that need be integrated.

Climate proofing ecological networks has to deal with many uncertainties, including statistical uncertainty (possible outcomes and their probabilities are known), scenario uncertainty (a plausible range of possible outcomes can be established but the relative probabilities of each possible outcome are largely unknown) and ignorance (outcomes unknown: unanticipatable surprises).
Approaches for dealing with uncertainty in climate change adaptation include: risk approach, anticipating design, resilience, adaptive management, and robust decision-making. These decision frameworks can be grouped into the predictive top-down approach and the resilience bottom-up approach. Top down explores the accumulation of uncertainty going from emission scenarios, to global climate response, to regional climate scenarios to produce a range of possible local impacts in order to quantify what needs to be anticipated. The bottom up resilience based approach starts at the impacted system, and explores how resilient or robust this system is to changes and variations in climate variables and how adaptation can make the system less prone to uncertain and largely unpredictable variations and trends in the climate. Resilience also means that the impacted system is adapted in such a way that its essential functions can recover more quickly after a shock and that restore times after damage and response time following early warning signals are made as fast as possible. This project further develops a system-oriented strategy: strengthening the resilience of the impacted system to climatic changes.

The project aims to operationalise the concept of resilience. Folke (2006) identifies a sequence of resilience concepts, from narrow to broad: (1) engineering resilience, (2) ecosystem resilience and social resilience, and (3) social-ecological resilience. The first two focus on recovery rate and withstanding shock respectively. The last focuses on the interplay between disturbance and reorganization. In the literature on resilience, the concept is currently defined as "the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks". Three characteristics of (social-ecological) resilience are identified:

1. The amount of change the system can undergo and still retain the same controls on function and structure
2. The degree to which the system is capable of self-(re)organization to accommodate external changes
3. The ability to build and increase the capacity for learning and adaptation

This relatively broad definition seems suitable for the Green Backbone that faces not only disturbing events (shocks; e.g. floods), but also disturbing trends (e.g. increased salt intrusion). On longer timescales, withstanding and recovering from singular disturbing events is insufficient. A resilient system should also encompass the dynamics to accommodate trends and co-evolve; to bounce back in better shape.

This project will develop and explore policy options and strategies that could enhance a system's resilience. Several studies propose resilience indicators for specific subsystems, aiming to provide a basis for quantitative evaluation of possible policy strategies (e.g. Adger, 2000, Carpenter et al., 2001, De Bruijn 2004). Other studies have taken a qualitative approach (Wardekker et al, in press). This project aims to combine and integrate quantitative and qualitative approaches to resilience.

The main question is: what could a resilience based system approach to climate change adaptation entail for a fresh water dependent Nature area?
- What are relevant possible disturbances of the Ecological network under various climate change scenario's?
- What are the essential values and functions of the Green Backbone system?
- How vulnerable is each of these functions to climate changes?
- In what way does the current policy framework for the Green Backbone take climate change into account and how is dealt with uncertainties surrounding climate change?
- What are the different alternate states of the system?
- What is the desirable (future) state of the system?
- In which state is the system at present?
- Which regime shifts could possibly occur as a result of the combined effect of climate change and other anthropogenic disturbances?
- How resilient is the system at present?
- What specific measures can be taken to enhance the resilience of the system?

B. Approach and methodology

The operational definition of a resilient system used in this study is: "a system that can tolerate disturbances (events and trends) through characteristics or measures that limit their impacts, by reducing or counteracting the damage and disruption, and allow the system to respond, recover, and adapt quickly to such disturbances". In this definition, tolerating disturbances is taken in contrast to resisting these. We will assess trends/impacts, define characteristics that make a system resilient, and use these to explore options and to specify and categorise how they can contribute to the system's resilience.
This study uses six 'resilience principles' from ecological and system dynamics literature (Watt and Craig) for generating resilience indicators and policy options in relation to adaptation of ecological networks of wetlands:

- Homeostasis: multiple feedback loops counteract disturbances and stabilise the system.
- Omnivory: vulnerability is reduced by diversification of resources and means.
- High flux: a fast rate of movement of resources through the system ensures fast mobilization of these resources to cope with perturbations.
- Flatness: the hierarchical levels relative to the base should not be top-heavy. Overly hierarchical systems with no local formal competence to act are too inflexible and too slow to cope with surprise and rapidly implement non-standard highly local responses.
- Buffering: essential capacities are over-dimensioned such that critical thresholds in capacities are less likely to be crossed.
- Redundancy: overlapping functions; if one fails, others can take over.

The approach builds further on Wardekker et al (in press) that applied these resilience principles to adaptation of an urban delta.

C. Scientific deliverables and results

- scientific report on the conceptual framework for operationalising resilience.
- scientific article in peer reviewed journal on resilience indicators and policy options for climate change adaptation of the Groene Ruggengraat.

D. Integration of general research questions with hotspot-specific questions

This project will mainly contribute to the hotspots "Ondiepe wateren en veenweidegebieden" and "Zuid Westelijke Delta" and "Biesbosch", but the results are expected to be applicable to all hotspots that search for resilient ways to adapt nature area's to climate change.

E. Societal deliverables and results

- Resilience based step by step approach for generating indicators and policy options
- Indicators for resilience customized for nature area's
- Policy options for increasing resilience of Groene Ruggengraat

F. Most important references (max. 15)

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Appendix 2-11

Project 5.2 (with work package 5)	
full title project :	Robustness analysis methods to support flood and drought risk management policy making
project leader:	Prof. Eelco van Beek
type of research:	PhD (Marjolein Mens)
duration:	four years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Decision-making about long-term water management is a complex process. It concerns designing, combining and deciding between various types of measures, together with different stakeholders working on different scales. Moreover, it is considered more and more important to take into account long-term changes in the system that may influence the effect of measures.

Decision-makers use a variety of criteria such as costs and benefits to be able to choose between strategies. In order to deal with uncertainties about future developments, additional criteria such as robustness and flexibility are suggested. Since a few years, decision-makers in the Netherlands have been referring to the concept of robustness (see for example: ARK (2007), Nationaal Water plan (2008), Ontwerp waterbeheersplan Zeeuwse eilanden (2008) and Ontwerp waterbeheerplan Brabantse Delta (2008)). They have the feeling that robust systems are preferable under the pressure of climate change, but cannot specify what makes a system more robust. Because a clear definition lacks, this leads to miscommunication among stakeholders resulting in a large range of robustness scores.

Because robustness is still not well defined, it is worth exploring its meaning and use for long-term flood and drought risk management. We hypothesize that the concept of robustness, when well defined, supports to explicitly deal with natural variability and future changes herein. This may support the development of strategies (combination of measures) and the decision between them.

The objective of the research is to improve the use of robustness in decision-making for long-term flood and drought risk management. We aim to enhance the applicability of the concept, by developing a practical method to assess alternative strategies for flood and drought risk management and guidelines to increase the robustness of systems.

The main research question is *whether and how the concept of robustness can aid decision-making about long-term strategies for flood and drought risk management.*

The following questions will be addressed:

1. What definition of system robustness is suitable for use in the management of flood and drought risk systems?
    1.1. How is robustness defined in ecological, social and economic literature?
    1.2. How does robustness relate to other, comparable, concepts such as vulnerability and resilience?
    1.3. How is robustness used in practice?
    1.4. Which definition is suitable for flood and drought risk systems?
2. Which indicators can be used to quantify robustness of flood and drought risk systems?
3. How can the robustness of flood and drought risk systems be increased?
    3.1. relation with Modern Portfolio Theory? (Jeroen Aerts)

What is the added value of robustness as decision criterion in flood and drought risk management?

B. Approach and methodology

The definition of system robustness used in this study is: "the ability of a system to cope with disturbances". In this study, the robustness of drought risk systems to natural variability will be assessed. Robustness is comparable to the concept of ecosystem resilience (Holling, 1973) and can be increased by increasing the resistance, measured by the maximal amount of disturbance that is needed to cause the system to react adversely, or increasing the resilience, measured by the amount of impact, the graduality of the impacts and the recovery capacity (De Bruijn, 2005).

Approach:

To develop the conceptual framework for robustness, we will make an overview of definitions and usages in literature and practice. As for literature, we consider robustness of ecological systems, robustness of economic systems and robustness of social systems. As for practice, we look into recent water policy documents from the Netherlands government (i.e. Nationaal Waterplan) and from Netherlands waterboards ('ontwerp waterbeheersplannen'). This is done together with theme 1.

The concept of robustness applies to different problem owners. This is especially relevant for drought risk management: a farmer will be interested in the robustness of his yield to drought, while a province will be interested in the robustness of the regional economy to drought periods. Different perspectives will lead to different conclusions about which measures to take. With the case of 'Groene Ruggengraat' we aim to demonstrate the effect of different perspectives.

Summary of approach (* indicates cooperation with theme 1):

- *Literature review: How is system robustness defined in literature and how is it used in practice?;
- *Development of a conceptual framework for robustness;
- Individual discussions with hotspot representatives about the framework;
- *Design of a framework to analyse the cases;
- Casestudies: application of conceptual framework on drought risk systems:
    - System description;
    - Robustness analysis, including long-term developments;
    - Design and assessment of strategies;
- *Reporting insights in the form of guidelines;
- Workshop with hotspot representatives to discuss guidelines and casestudy-results;
- *Adjust robustness framework

C. Scientific deliverables and results

Two scientific articles in peer reviewed journals:
- one the conceptual framework and the Westerschelde (together with theme 1);
- one on the application in one or two drought risk management cases.

D. Integration of general research questions with hotspot-specific questions

This project will mainly contribute to the cases Groene Ruggegraat and Zuidwestelijke Delta
The conceptual frameworks for robustness will aid the assessment of drought risk management strategies in WP-6. The guidelines can be used by decision-makers who are concerned with the long-term planning of areas that are at risk of flooding and/or at risk of drought.

E. Societal deliverables and results

- Guidelines for the development of robust policy strategies for drought risk management;
- Indicators for the quantification of robustness

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Appendix 2-12

Project 5.3 (with work package 5)	
full title project :	Towards robust policy making for fresh water supply
project leader:	Prof dr ir W.A.H. Thissen
type of research:	Postdoc/senior researcher
duration:	4 years - part-time

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

As indicated in the theme 5 general description, decision making on long-term strategies for fresh water supply is confronted with a variety of uncertainties, including climate variability, various potential impacts of climate change, de degree and speed of climate change, economic and agricultural conditions, other relevant social developments. Different approaches exist or are under development that specifically orient to dealing with such uncertainties (ref. Dessai and Van der Sluijs, 2007).). While the two other projects in the work package focus mainly on so-called robust or resilient design of socio- ecological systems as an answer to variability uncertainties (with a particular emphasis on natural systems in project 5.1), this project concentrates on so-called robust decision making (Lempert et al., 2003). Robust decision making is particularly suited to dealing with so-called deep uncertainties: situations where possible developments can be imagined, but no reliable estimates can be given about their probabilities and outcomes. This includes the types of uncertainties that are often dealt with using scenario-approaches, but also so-called wild-cards or surprise scenario's should be included, and situations in which there is no agreement about what models best represent system behaviour. An example of application of the approach to a regional water supply problem in California is given in (Groves and Lempert, 2010).

The approach – which is still under development – combines a broad analysis of uncertainties and their possible impacts (Lempert et al., 2003; Agusdinata, 2008) with an assessment of the performance of selected policy alternatives under a wide range of possible assumptions about the future. The insights thus gained enable analysts and policy makers to identify the conditions under which policies will perform well, and conditions under which policies might fail. They may then select a base policy that will do well under most circumstances, identify future conditions under which policy adaptations are desired, as well as the type of adaptations. The insights gained may also help distinguish between more flexible policy options that allow for easy adaptation as circumstances change, and less flexible ones which may lead to lock-in situations.

Central research questions in the project will be:

- what typical decision situations for regional long-term fresh water supply exist in the Netherlands?
- which uncertainties will have an impact on long-term fresh water supply and demand for these situations?
- what policy options do exist or can be thought of for these situations?
- to what extent and under what conditions is exploratory modeling and analysis suited as an approach to assess the performance of these various policy options under a wide set of possible futures?
- what criteria can be relevant for choosing among these policy options, with a particular view to how they deal with uncertainties (flexibility? Least-regret? Robustness?)
- what general recommendations can be given for the selection of a preferred policy strategy to deal with uncertainties, depending on the situation characteristics?

B. Approach and methodology

First step in the approach will be to identify a limited number of typical decision situations regarding fresh water supply in the Netherlands. For example, the situation in the western part of the country will be essentially different from the one in the high part of the country. Different factors and mechanisms come into play, and different associated uncertainties. While there will be a focus on the selected case studies which are all situated in the western part of the Netherlands (see WP6), at least one situation will be included that is representative for the 'high' part of the country.

Second, for each situation the relevant, long-term uncertainties will be identified. These include uncertainties about external developments (such as climate change and economic developments) as well as uncertainties about the

internal functioning of the region to be studied (e.g., abut the impacts of future changes on water use, the quality of ecosystem services, the economic costs and benefits of local agriculture, etc.). The framework developed by Walker et al. (Walker et al., 2003) will be used as guidance in this effort.
Third, the spectrum of possible policy strategies for each selected situation will be identified. What options are available will of course depend on the characteristics of the situation. One might wait and see what developments will occur, decide to invest in flexibility options, over-dimension the capacity of water ducts, etc. etc. (see e.g. Klinke and Renn, 2002; Van der Sluijs, 2005).
Fourth, a framework will be developed for evaluation of policy options under uncertainty. In addition to the usual set of criteria such as costs, benefits, harm to the natural system, etc., special attention will be given to the uncertainty dimension. In coordination with the PhD (project 5.2), policy robustness indicators will be developed, and these may be different for the different case situations.
Fifth, where feasible the principles of Exploratory Modeling and Analysis (Agusdinata, 2008) will be used to explore the range of possible impacts of the policy options under a wide range of possible future circumstances. This will imply a conceptual analysis of the flexibility of different decision sequences (decision 'pipeline' approach), as well as the use of relatively simple computer models for a more extensive analysis. When available, use will be made of (simplified versions of) existing models. If new models need to be developed, this will require additional efforts, and model availability will have an impact on the number of different cases that can be explored in depth within the temporal and financial boundary conditions of the project.
Sixth, combining the results of the uncertainty impact analysis with the evaluation framework, a so-called adaptive policy strategy is developed (Walker et al., 2001). To start, a selection is made of the more robust policy options: those that will perform reasonably well under a wide range of possible circumstances. In addition, the conditions under which this policy will perform less than desired are identified, and measures or adaptations that would improve policy performance under such conditions are defined.
Interaction with and support of local experts and stakeholders in the cases will be important in most of not all of these steps.
Finally, attention will be given to the overall, more general lessons based on the situation-specific work. These will relate to both the utility of and possible improvements in the methodology, as well as to the policy content.

C. Scientific deliverables and results

The project will deliver:

- comprehensive insight into the various uncertainties of relevance for long-term planning in fresh water supply in the Netherlands, and their relevance to mostly regional policy decisions to be made in the short term
- a basic insight in what kind of policies will perform best, depending on the characteristics of the situation and of the uncertainties
- one or more evaluation frameworks specifically geared to evaluation of long-term water supply policies under uncertainty
- insights into the applicability and limitations of Exploratory Modeling and related approaches for long-term fresh-water policy making in the Netherlands, and general guidelines for their application

Results will be documented in reports for each of the cases that will be studied in depth, and in a number of internationally reviewed papers, partly in cooperation with the researchers of projects 5.1 and 5.3, and WP6.

D. Integration of general research questions with hotspot-specific questions

A selection of the policy dilemma's faced by the hot spots, and by water management authorities in general, will be used as empirical case material for developing, applying and evaluating the approach. This will include at least the Haaglanden and the Zuid-Beveland cases that will be elaborated in WP6.

E. Societal deliverables and results

The policy makers in charge of decision making for the selected cases will get guidance in their quest for long-term robust policies
Other policy makers and analysts will obtain a methodology and guidance to systematically address deep uncertainties in their long-term strategy development
As a result, water supply policies will be more effective in the long run.

F. Most important references (max. 15)

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Appendix 2-13

Project 6.1 (with work package 6)	
full title project :	Case study Groene Ruggengraat - Climate proof water and land use in coastal meadows of the Netherlands
project leader: **team:**	Jeroen Veraart Arjen de Vries, Ad Jeuken, Martha Bakker (theme 3), Saskia Werners
Type of research:	Applied
Duration:	2010-2014

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Much of the world's population lives in coastal areas and delta regions. Fertile soils, presence of water resources and transport possibilities make deltas ideal settling areas. On the down side they are inherently vulnerable to natural hazards. Expanding economies and the intensification of agriculture place considerable pressure on fresh water resources and ecosystems, such as coastal meadows. The coastal meadows in the Netherlands are characterized by the interplay between urban and rural developments. The urban agglomerate that borders the coastal meadows is commonly referred to as Randstad. The water-rich meadows, referred to as ' Groene Hart', combine the functions of agriculture (mainly dairy farming and along the borders greenhouse horticulture), nature, and recreation for about 5 million people. It is a cultural landscape characterized by water systems such as lakes and pools as well as numerous ditches and canals. As a result water management in this area is complex. In addition the area is on the short term (<2025) under pressure due to expansion of the Randstad periphery, soil subsidence (up to 1 cm/year), the demand for for water retention areas, and water nuisance related to climate change (Woestenburg, 2009; Querner et al., 2009).

A rising sea level imperils on the long-term (>2050) the fresh water availability in this region as salt water penetrates further inland via the rivers and through the subsoil (Deltacommissie, 2008). To reduce the impact of salt water intrusion for agriculture the amount of freshwater necessary to flush out saline water will increase.Warm dry summers with freshwater shortages will occur more frequently according to two of the four KNMI climate change scenarios (van den Hurk et al., 2006). Higher temperatures and the changes in fresh water availability will change the conditions for terrestrial and aquatic ecosystems in the coastal meadows. Some species and certain ecosystems will not be sustainable under the changed conditions; new (exotic) species may flourish. Policies, such as Natura2000 and the EU water framework directive that are concerned to preserve present conditions and species will probably be neither sustainable in the face of climate change. Agriculture and horticulture will encounter both opportunities and risks. The foreseen changes in rural and climate European policies, such as a new directive for emission trading (2008) might allow dairy farmers on low-lying peatland to diversify and to climate proof their activities, including the reduction of greenhouse gas emissions In future post-Kyoto policies this type of ecosystem services that increases the resilience of rural landscapes to climate change (Werners, in press; Werners, 2009) might be awarded in (subsidized) economic income.

Aim: The project investigates/evaluates local cross-sectoral strategies (agriculture, nature conservation, drinkwater production)in the Dutch coastal meadows that are aimed to minimize the increasing gap between regional supply and demand of freshwater, given the context of climate change and trends in water demand. Evaluation criteria for these local strategies include resilience, robustness and flexibility. Those criteria are applied to assess risks for salt damage, drought damage and greenhouse gas emissions for agricultural practices and biodiversity.

Research questions

- Under which spatial and season salt-freshwater gradients and supply/demand scenario's it is possible to fulfill both socio-economic water demand (agriculture, drinkwater production) in conjunction with nature development and biodiversity policies in the coastal meadows?
- What are the implications of the proposed local adaptation strategies by scientists and stakeholders for the

short-term policy objectives for the region as formulated by the European Water Framework Directive, Bird directive and Natura2000?

B. Approach and methodology

Approach:
Step 1: Problem framing: assess the future (perceived) gap between freshwater supply under 2 different baseline scenarios for future water demand (without interventions) on local level for biodiversity conservation, agriculture and drinkwater production.

Step 2: Selection and quantification of key indicators to assess the mismatch between freshwater supply and demand under the baseline assumptions (without intervention) in order to assess the magnitude of the (future) mismatch.

Step 3: Design of 2 alternative futures, that include a local portfolio of measures (water management, water technology and land use change) aimed to reduce the identified mismatch from step 1. The alternative futures are based upon the following *water management paradigms:*

- *Resist impacts of climate change on fresh water resources*
- *Cope and live with impact of climate change on fresh water resources*

The local portfolios of measures will also be discussed in an international workshop for which people will be invited that are involved in management of coastal meadows in other countries.

Step 4: Those alternative futures are evaluated based upon the selected key indicators and described baseline scenario's (step 1).

All 4 steps are executed in dialogue between the scientists from the consortium and the regional experts and policy makers. In this way it is possible to identify differences and consensus in perceptions regarding future drought and salt damage risks (Euro/ha) for biodiversity and socio-economic functions in the Dutch coastal meadows (i.e. joined fact finding). The following timeframes are used:short term(2009 – 2015), Medium term (2015 – 2050) and Long term (2050 – 2100).

The project will build upon the results, regional land use/water management scenario's and public-private networks of the programme "Waarheen met het Veen" (Woestenburg, 2009), as well as on the results of the so-called Groene Hart study (forthcoming). Therefore it is chosen to apply the approach on local level. Possible local case studies, selection will be done in dialogue with the hotspots, include: Reeuwijkse plassen, Zevenhovense polder, Nieuwkoopse plassen, Zegveld, Midden Delfland and Waalblok. Issues of problem shifting of water scarcity issues from one region to another, suboptimal outcomes for the meadow lands as a whole will be identified. However, the (quantified) impact of those type of scaling issues are beyond the scope of this study and will be addressed in the National Delta programme.

The methodology includes:

- Expert judgment by scientists, practical experts and regional policy makers in workshops. Those workshops aim also to support foreseen modeling activities in work package 1,2 and 3. All steps in the approach are supported by desktop studies and literature survey.
- By means of (interview) surveys and spatial analysis of (changes in) land use types (nature, agriculture, recreation), land users' support for certain adaptation portfolio's and their attitude towards ecosystem service provision, will be identified. The results of this survey will be used to model the future distribution of different farmer and nature conservationist types with agent-based modeling (Bakker and Doorn, 2009; Filatova et al., 2009) in co-operation with KvK theme 3.

Disclaimer: the methodology described gives a rough outline of the project. The final research ambition (i.e. number of scenarios, number of key indicators, number of time frames and number of publications) will depend on the available budget, currently discussed with the involved stakeholders.

C. Scientific deliverables and results

(1) The selection and quantification of the key indicators to assess the mismatch between freshwater supply and demand under different scenarios. The will be described in 1 or more scientific multi-author papers (inclusive the involved PhD from other projects) as this generic result is also usefull for other coastal meadow areas in the world.
(2) This project will contribute, together with project 14 and15 and workpackage 5, to a peer-reviewed multi-author paper that will reflect on the level of achieved inter/multi/trans-disciplinarity and the usefulness of the chosen approach.
(3) This project provides on a local scale opportunities to improve models that are part of the National Hydrological Instrumentarium (report)

D. Integration of general research questions with hotspot-specific questions

The approach is designed in order to support hotspot specific questions as much as possible. The local cases will be selected in dialogue with the hotspots. The two main research questions (see section A) support raised questions by Hotspot Haaglanden, Hotspot Rotterdam, province Utrecht, Zuid-Holland,waterboard Schieland and Krimpenerwaard, water board Hollandse Delta and STOWA about the implication of climate change and changes in socio-economic water demand for the Water framework directive and Natura2000.

E. Societal deliverables and results

For each selected local pilot (maximum 3) a description of portfolio's of operational measures to climate and salt proof freshwater demand and supply, tailored to local and regional circumstances will be delivered (**3 reports**). Not only the reports but also the set up of the project will provide both regional and national authorities with a selection of viable strategies to contribute to regional self-sufficient and climate proof water supply system.

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Appendix 2-14

Project 6.2 (with work package 6)	
Full Project Title:	Case study Haaglanden - Towards a more robust, self-sufficient fresh water supply of the Haaglanden region
Project Leader:	Dr. Ir. M.A.A. Paalman (KWR)
Type of Research:	Desk and field studies
Duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

Problem definition

Climate change projections for the Netherlands reveal the risk of periodic shortage of fresh water supply in the future (Loaiciga *et al*., 1996). During periods of summer drought, the Haaglanden region will depend more heavily on surface water supply from the major rivers. However, due to the effects of climate change, the intake water from the Rhine/Meuse basin may become (periodically) brackish due to periods of low river discharge and salinity pressures from rising sea levels (Middelkoop *et al*., 2001). In addition, in order to increase the ecological sustainability of the Deltaworks region, structural management alterations are foreseen and this can have profound implications for fresh water availability in the Zuidwestelijke Netherlands (e.g. Haaglanden region). In order to ensure economic sustainability and growth in the area, it is crucial to have a sufficient continuous supply of fresh water.

Aim

The goal is to promote regional water self-sustainability in an area of high intensity industry (Rotterdam region) and greenhouse horticulture. This research project will identify and evaluate the feasibility of alternative regional sources of fresh water in a deltaic, saline environment. In addition, adaptations to or optimization of current water supply infrastructure will be analyzed given the projected impacts of climate change. To accomplish this, innovative technological methods will be assessed and implemented on pilot-scale if appropriate.

Research questions

The main research questions have been designed to address general issues identified in work packages 1, 2 and 4 in a case-specific environment (Haaglanden).

The first main research question is: How can we make the Haaglanden region's water supply more self-sufficient?

- What is the potential of alternative sources for local or regional freshwater supply and what is the development of the demand of fresh water by the sectors? (project 4.2)
- What are the PRO's and CON's of utilizing each of these sources in terms of availability, continuity, water quality, transport, treatment technology, costs, environmental impact and regulations? (project 4.2)
- What proactive water management measurements can be taken in periods of drought?
- How will salinity and groundwater-surface water interactions be affected by climate change?
- How do we improve the buffering capacity and storage of fresh water? This question will be answered in co-operation with project 2.1 and 4.1.
- What innovative disposal solutions exist for the saline residue (brine) that is generated as a byproduct of desalination? (project 4.2)

The second main research question is: How the main water system in the future can contribute to the regional fresh water supply of Haaglanden? (project 1.2)

- How will climate change affect fresh water (salinity) at the major intake points of surface water (Gouda and Bernisse)?
- Will there be an adequate supply of water from the main surface water network system to meet demand in Haaglanden?

B. Approach and methodology

Disclaimer: The methodology described below just gives an outline of the research possibilities. The final research ambition will depend on the project's budget, which is not defined yet as the amount of co-financing generated by the different stakeholders is still unclear.

Approach

The study focuses on ways to obtain a more regionally self-sufficient water supply that is less dependent on surface water (the main river system). In particular, this will focus on the greenhouse and industrial sectors, as they are the most important economic activities in the area. The approach will focus primarily on using the system's own regional water sources (groundwater, surface water, rain water, waste water) more efficiently. This will result in a more sustainable, climate-proof water system with balanced supply and demand. This approach and methodology will be further developed in coordination with regional stakeholders and through consultation with a project advisory board comprised of local experts (Province of South Holland, Waterboard of Delfland, Municipality of Westland, LTO/Glaskracht (greenhouse sector)).

Methodology

1. How can we make the Haaglanden region's water supply more self-sufficient? (desk and field study)
    - Describe the current and future situation of the greenhouse and industrial sectors in the Haaglanden region (based on available literature and interviews with experts).
    - Inventory of the current and future fresh water demand in the Haaglanden region. We will base this inventory upon available local knowledge and experts from WUR with relevant experience (A.van der Maas *et al,* 2009).
    - Inventory and quantify primary and alternative sources of fresh water in the Haaglanden region (brackish groundwater, reuse of wastewater, rain water, use of excess groundwater of former DSM Delft). Local expert knowledge from the Delfland Water Board will be highly valuable for this inventory.
    - Perform desk research on the technological opportunities to make the various sources of water suitable for surface water and the greenhouse and industrial sector as Memstill
    - Assess the feasibility of the relevant alternative water sources in terms of availability, continuity, water quality, treatment technology, costs, laws and regulations.
    - Study the possibilities of aquifer storage and recovery (ASR) and other fresh water buffering techniques in a brackish groundwater environment (in association with Projects 2.1 and 4.1).
    - Further develop a groundwater-surface water model to quantify changes in the supply of fresh water, especially in dry periods, in the Haaglanden region as a result of climate change (together with WP 2.2).
    - Inventory of past and current projects on brine in the region (eg. study by the province of South Holland). The results of these projects will be reviewed in terms of geographical feasibility and technological aspects.
    - Based on the review of past and current projects, identify potential brine disposal techniques that could be implemented on pilot-scale in Haaglanden. Possible examples include evaluation of brine injection into confined saline aquifers, and the potential of water technology (crystallization) to produce a solid end product which may be reused for industrial applications (the "no-waste" concept of TNO).

2. How may salinity levels at the major intake points of the main water system (Bernisse, Gouda) vary over time, according to different climatic and hydrologic scenario's and upstream (transboundary) water management? What will be the consequences of these projected variations for water supply to the Haaglanden region?

C. Scientific deliverables and results

The proposed research will result in the following deliverables:

1. Quantification of the demand and regional availability of fresh water in the Haaglanden region
2. Identify and quantify the potentials and hurdles of (innovative) water treatment technology (desalinization, transport system, Memstill technology).
3. Ditto of innovative brine treatment technology like the crystallization process and brine injection into saline confined aquifers.

Deliverables will be published as a scientific report (items 1-4). In addition, several publications in national, professional journals are anticipated.

D. Integration of general research questions with hotspot-specific questions

A report from the steering committee of the Zuidwestelijke Delta to the Secretary of State on Water Management strongly recommends research to improve regional water self-sufficiency (Stuurgroep Zuidwestelijke Delta, 2009). Improving regional self-sufficiency in water supply is an important challenge to all hotspots in brackish water environments that face potential fresh water shortages (Zuidwestelijke Delta, Haaglanden, Rotterdam, Schiphol region and the Waddenzee). The hotspot areas Zuidwestelijke Delta and Haaglanden are particularly interested in research that could enhance the self-sufficiency of their water supply (Vries, A. de, 2009).

E. Societal deliverables and results

The results of the research will provide regional and national authorities with a selection of practical and effective strategies to contribute to regional self-sufficient water supply. As such, these authorities can utilize the knowledge to design robust adaptation plans that will mitigate the effects of climate change on water resources. This will help ensure long-term environmental and economic sustainability for regions by providing a continuous, secure source of fresh water.

The provision of a regional self-sufficient water supply in saline environments is important for all deltaic and coastal regions. The knowledge and concepts generated in this research can be utilized to help develop alternative water supply in similar regions worldwide. In addition, newly-developed or optimized processes for treatment and disposal of desalination brine with minimal environmental effects are relevant for all countries that operate desalination plants (Middle Eastern countries, Spain, Australia). Addressing this environmental issue could open up new possibilities for the wider implementation of desalination plants globally.

F. Most important references (max. 15)

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Remark: see additional references at the relevant projects (WP1, WP2 and WP4)

Appendix 2-15

Project 6.3 (with work package 6)	
full title project :	Case study Zuidwestelijke Delta- Climate proof, and sustainable water use in Dutch Delta area
project leader:,	Dr. A.C. (Arjen) de Vries
type of research:	Applied
duration:	4 years

Description project (max. 1500 words – A through E)

A. Problem definition, aim and central research questions

The South-western Delta consists of the estuaries of the rivers Rhine, Meuse and Scheldt. Interactions between sea, rivers and land are characteristic for the whole area. The area is important as strategic freshwater reservoir for the rural area to the east, for river-discharge regulation (peak discharges of the Rhine-Meuse are diverted from the port of Rotterdam), for recreation (aquatic and cultural), aquaculture (shellfish, lobster, etc.), nature (especially relict intertidal areas), and as gateway to the port of Antwerp (Westerschelde). While the Deltawerken are still an international icon for Dutch water management, current land-use and water-management plans put emphasis on their adverse environmental impacts (water quality), as well as prospected climate change. Currently water management strategies and land-use plans are reconsidered in order to minimize flood risks, optimize freshwater availability, reduce salinisation, and improve water quality and biodiversity, as most recently described in the National Water Plan (2008). Two main fresh water basins, constructed as part of the Delta Works, are the Haringvliet and the Volkerak-Zoom lake. Large parts of the Delta have no direct access to fresh water, and are solely depend on rainfall and natural storage.

The major challenge is to develop the southwest part of the Netherlands in a sustainable manner, including the restoration of the estuarine dynamics under a changing climate, thereby safeguarding the freshwater supply for agricultural and other uses. A number of possible approaches have been identified:

- supply follows demand, i.e. guarantee fresh water supply artificially by separation from the natural environment (external supply)
- demand follows supply; i.e. adaptation of water-dependent sectors to the natural environment
- a combination of 1 and 2 including the applications of innovative technology

The current project focuses on an area without direct access to fresh water reservoirs. However, given the expected higher water demands in future and the impact of especially salinization, there is a clear need for a strategy towards a sustainable and self-reliant water management system under climate change. For the content the project continues to develop further insight in the processes of salinization and possible effective measures, both at the regional and local scale. The project is based on results from projects such as 'Living with Salt Water, (www.levenmetzoutwater.nl), the Meta-studie (De Vries et al., 2009), that made a first reconnaissance of the existing and expected fresh water situation of the Zuidwestelijke delta and work of Oude Essink (2007) and Post (2004) on the physical aspects of salinization processes.. Although the case focuses on a typical Dutch area, the projects has a clear international relevance. Many low lying Deltas face very similar problems such as increased salinisation (both internal and external) and increased pressures. The results of the study give insight in the physical processes and on strategies on how to deal with the occurring issues.

Aim: The current project investigates whether new approaches to the supply and demand of fresh water are desirable or required in the context of a changing environment, in an area located in the South-western Delta. This 'freshwater claim' will be compared with other water, agricultural and climate policy objectives in this area. The exact location of the project area within the South-western Delta will be identified in a later stage.

Research questions

The main research questions have been designed to address the more general issues as identified in the other work packages.

1. How to develop the project area in a more sustainable manner, including the restoration of the estuarine dynamics under a changing climate, thereby safeguarding the freshwater supply for agricultural and other uses and making the dependency on external water supply smaller.
2. What is a feasible strategy to reach that goal and what are viable options for land use, water-management, and water-technology for the long-term future.

B. Approach and methodology

Approach

The study focuses on ways to reach a more regionally self-reliant water supply system that is less dependent on external freshwater supply. It focuses primarily on different alternatives to utilise the areas own water resources (surface water, groundwater, rainfall, waste water) more efficiently or for example through storage. Based on the existing hydrological system and the expected changes in terms of climate change and land use, a strategy will be developed that will result in a sustainable, climate proof water system with balance between supply and demand. This strategy will be further developed in an open dialogue with the different stakeholders and through consultation with the project advisory board. The board will include experts from the Province of Zeeland, Province of Brabant, Water Board ZuidHollandse eilanden, Water Board Brabantse Delta, and ZLTO (agricultural sector).

Results from other work packages will be input for the current project. Also experts and researchers from the other work packages will participate actively. The methodology described gives a rough outline of the project. The final research ambition and budget will depend on the results of ongoing discussion with the involved stakeholders. Also the specific research area within the Zuidwestelijke Delta will be defined at a later stage. However, it will probably include the area of Zuid-Beveland

Methodology

1. Baseline study
- Hydrological system analyses, including all possible water resources mentioned before, considering both water quantity and water quality
- Inventory of actual and (expected) future water demand and supply for the different sectors
- Inventory of expected changes in fresh water supply, due to climate change. This inventory includes both internal and external salinisation processes.
- Inventory of potential solutions offered by water technology (e.g. desalination, effluent reuse, brine disposal options)

2. Strategy development
- Development of a strategy for a sustainable, climate proof water system, based on the baseline study and stakeholder consultation
- Inventory of portfolios of area specific measures (both technical and institutional)
- Consultation with the stakeholders on strategy and measures.

A number of specific aspects will be looked at, such as:
- Opportunities for self-reliance of the horticulture sector in Zuid- Beveland (area located in the South-western Delta) through storage at the local scale
- Nutrient load from the groundwater to the surface water

C. Scientific deliverables and results

The proposed research project will result in the following deliverables:

1. Feasibility study of a regional self-reliant water supply, for a region in the South-western Delta.
2. Combined analyses of other case studies to the crucial factors for self-reliance
3. Opportunities for self-reliance of the horticulture sector, including possible measures
4. Insight in the physical processes and on strategies on how to deal with a changing environment under climate change and increased pressures in low-lying delta areas.

D. Integration of general research questions with hotspot-specific questions

A report from the steering committee of the Zuidwestelijke Delta to the Secretary of State on Water Management, strongly recommends research for improving regional water self-sufficiency (Stuurgroep Zuidwesterlijke Delta, 2009). Improving regional self-sufficiency in water supply is an important responsibility to all hotspots in brackish water environments that face potential fresh water shortages (Zuidwestelijke Delta, Haaglanden, Rotterdam, Schiphol region and the Waddenzee). The Zuidwestelijke Delta and Haaglanden hotspots are particularly interested in research that could enhance the self-sufficiency of their water supply.

E. Societal deliverables and results

The results of the research project will provide regional and national authorities with a selection of viable and effective strategies to contribute to a regional self-sufficient water supply system. As such, these authorities can utilize the knowledge to design robust adaptation plans that will mitigate the effects of climate change on water resources. This will help ensure long-term environmental and economic sustainability for regions by providing a continuous, secure source of fresh water.

The provision of a regional self-reliant water supply in saline environments is important for all deltaic and coastal regions. The knowledge and concepts generated in this research can be utilized to help develop alternative water supply in similar regions worldwide.

F. Most important references (max. 15)

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Appendix 3

nr 1 Track record research group	
Name research group	Deltares – research groups 'Scenario and Policy Analysis', 'Fresh Water Systems' and 'Subsurface and Groundwater Systems'
Research Profile	Deltares is an independent institute for delta technology encompassing and building on the forces of the former Delft Hydraulics, GeoDelft, and parts of TNO and Rijkswaterstaat. The institute employs 800 people. Deltares has more than 80 years of experience in research on hydraulics, hydro-engineering and geo-engineering. In the last decades, the emphasis of the research has shifted towards policy analysis, future outlooks and integrated management of coastal zones, water resources and river basins. Drought risk management and climate change are on the research agenda since about 1990. Deltares is involved in numerous projects all over the world and has co-ordinated numerous international project consortia in 5 continents, mainly dealing with integrated water resource management, coastal zone management and flood and drought risk management. It has structural co-operation with various universities and research organizations in the Netherlands and abroad. Deltares is responsible for the majority of the strategic research on water management for the Ministry of Public Works and Water Management, and provides policy support and advice to this and other national authorities. Deltares was a lead organization in providing technical support for the recent Delta commission.
Main research themes	In this proposal several units and/or research groups are involved. The unit *Scenarios and Policy Analysis* focuses on research for policy making at strategic and operational level, with special emphasis on long-term planning and flood and drought risk management at the national level, but the group also participates in regional and local studies for climate vulnerability assessment, planning and implementation. The unit *Subsurface and Groundwater Systems* aims to contribute to sustainable, optimal groundwater conditions and/or profitable use of the groundwater resources, well tuned to integrated water resources management and to other policy fields such as environmental management and nature conservation. The unit *Fresh Water Systems* carries out research on the physical aspect of fresh water systems in relation to the management issues involved such as European Water Framework Directive. This unit covers the disciplines hydrology, river morphology, water quality and ecology.
Main scientific achievements	Deltares plays a prominent role in national scenario studies on droughts and climate change (Netherlands Drought Study, "Klimaatbestendigheid Nederland Waterland", Waterplanverkenningen). It is active in developing new concepts for assessing climate impacts and dealing with uncertainty in future scenario's ('adaptation tipping points', assessment frameworks for climate and spatial planning, perspectives). Deltares is the national institute for hydrological model development for ground- and surface water including water quality processes.
10 key publications	1. Kwadijk J.C.J., Jeuken, A and Waveren H. (2008).De klimaatbestendigheid van Nederland Waterland. Verkenning van knikpunten in beheer en beleid voor het hoofdwatersysteem. Deltares T2447. 2. Haasnoot, M; Middelkoop, H.; Beek, E. van; Deursen, W.P.A. van (2009). *A method to develop sustainable water management strategies for an uncertain future*. Sustainable Development, Wiley. 3. Beek, E. van; Haasnoot, M; Meijer; K.M., Delsman; J.R., Snepvangers, J.J.J.C.; Baarse, G.; Ek, R. van; Prinsen, F.G., Kwadijk, J.C.J.; Zetten, J.W. van. (2008). *Verkenning kosteneffectiviteit van grootschalige maatregelen tegen droogteschade als gevolg van de G+ en W+ klimaatscenario's.* Deltares.

nr 1 Track record research group	
	4. Beek, E. van. *Managing Water under Current Climate Variability*, chapter in book 'Climate Change Adaptation in the Water Sector', edited by F. Ludwig, P. Kabat, H. van Schaik and M. van der Valk, Earthscan, UK 5. Offermans, A; Valkering, P;, Haasnoot, M, Beek, E. van;; Middelkoop, H. (2008). *Advies van de Deltacommissie vraagt breder perspectief* (in Dutch), H2O / 20 - October 2008 6. Stuurman, R., Baggelaar, P., Berendrecht, W., Buma, J., Louw, P., de, Oude Essink, G.H.P. (2008). The future of Dutch groundwater resources under the pressure of climate change (in Dutch: Toekomst van de Nederlandse grondwatervoorraad in relatie tot klimaatverandering), TNO-report 2008-U-R0074/B, VROM, 85 p. 7. Middelkoop, H.; Kwadijk, J.C.J. (2001). Towards Integrated Assessment of the implications of global change for water management, *Phys. Chem. Earth* (B) 26, No. 7-8 8. Mulder, J.P.M.; A.J.F. van der Spek (2008). Climate change and coastal zones: perception and scale., In: Book of Abstracts *International Conference on Coastal Engineering*, August 31 - September 5, 2008, Hamburg, Germany, p. 404. 9. Claessen, F., Van de Guchte, C., Van der Most, H., Oosterberg, W., Portielje, R. (2008). *Hoe veranderen andere landen mee met het klimaat? Internationale verkenning van klimaatadaptatie, met name in relatie tot het waterbeleid.* Rapport KLIMINT-project. Delft / Lelystad / Utrecht. 33 pp. 10. De Bruijn, K.M. (2005). *Resilience and flood risk management: a systems approach applied to lowland rivers*. Delft Hydraulics Select Series 6, Delft. see further: http://www.deltares.nl/xmlpages/page/deltares/publicaties

nr 2 Track record research group	
Name research group	Wageningen University, SEG Soil Physics, Ecohydrology, and Groundwater Management
Research Profile	Wageningen University and Research Centre (Wageningen UR) is a cluster of internationally-leading knowledge institutions providing education and scientific and applied knowledge in the field of life sciences and natural resources. Wageningen UR approaches issues in these fields from the perspectives of various disciplines, with an integrated approach and in close collaboration with governments, companies, stakeholder organisations, citizens, and other knowledge institutions. The Environmental Science Group of Wageningen UR is formed by Alterra and 21 Chair groups of Wageningen University and focuses on four main topics: rural development, biodiversity and ecosystem services, climate change and adaptation, and risk management. Our expertise related to this research proposal especially concentrates on: • Environmental, Agro- and Ecosystems Hydrology • Crop Production in relation with Soil and Water Salinity Two chairs of Wageningen University, and Alterra teams of the Environmental Science Group (ESG) are involved: Department Earth System Science and Climate Change (ESS-CC prof. Pavel Kabat) and Alterra teams, Integral Water Management (IW) and Integrated Water Resources Management (IWRM), Department Soil Physics, Ecohydrology, and Groundwater Management (SEG prof. Sjoerd van der Zee) of the Centre for Water and Climate, team Ecological Modelling and Monitoring (EMM) of the Centre for Landscape. For SEG, research is focused on the transfers of water, energy and solutes (chemicals) in groundwater, soil and rootzone and to a lesser extent crops/vegetations in the context of primary production, contamination, and ecology. Research is both fundamental and practical, both modelling and laboratory/field experimental in nature. Since a few years, the combination of physical (water, chemical transport), chemical (site factors), and biological/ecological (acidity, nutrients, pesticides, contaminants) aspects are integrated.
Main research themes	1. Ecohydrology (incl Agrohydrology) of wetlands, peatlands, semi arid regions, Dutch nature reserves) 2. Salinity and Sodicity (of Dutch coastal regions such as Zeeland; semi arid regions such as Australia, Southern Africa, Spain) 3. Contaminant Hydrology (transport of multicomponent mixtures, pesticides, metals, nutrients, organic compounds such as de-icing agents) 4. Earth Surface Processes (surface runoff, erosion)
Main scientific achievements	The SWAP (Soil Water Atmosphere Plant) model, used by 150+ users, worldwide, and integral tool in (1) Salt Tolerance Assessment Framework (Dutch ministries) and (2) EU pesticide admission policies, is developed by SEG in cooperation with Alterra. The Feddes function, cited by numerous scientific publications, on evapotranspiration/yield reduction for dry soil and wet (anaerobic) soil, and salt effects on crops developed at SEG The POT, polymer tensiometer, which has been developed during the past five years and is the only soil water pressure measurement device that can measure the entire relevant water pressure range (20 times larger than the range of conventional tensiometers) First ecohydrological papers that take into account the effect of groundwater on the rhizosphere layer. Insights in pesticide transport, that illustrate the relative unimportance of soil chemical interactions as compared with physical and biological processes, that will affect

nr 2 Track record research group	
	pesticide screening profoundly in EU
10 key publications	1. R.A. Feddes, G.H. de Rooij, and J.C. van Dam (2004). Unsaturated-zone Modeling, Progress, Challenges, and Applications, Kluwer Ac. Publ., 364 pp. 2. Van der Ploeg, M.J., H.P.A. Gooren, G. Bakker, and G.H. de Rooij (2008). Matric potentials measurements by polymer tensiometers in cropped lysimeters under water-stressed conditions, Vadose Zone Journal 7, 1048-1054. 3. Vervoort, R.W., S.E.A.T.M. van der Zee (2008). Simulating the effect of capillary flux on the soil water balance in a stochastic ecohydrological framework, Water Resour. Res., Vol. 44, W08425, doi:10.1029/2008WR006889. 4. Witte, J.P.M.; Torfs, P.J.J.F. (2003). Scale dependency and fractal dimension of rarity Ecography 26 . - p. 60 - 68 5. Q. de Jong van Lier, J.C. van Dam, K. Metselaar (2009). Root Water Extraction under Combined Water and Osmotic Stress, SSSAJ: Volume 73(3). 6. Homaee, M., R.A. Feddes, and C. Dirksen (2002). Simulation of root water uptake III, Non uniform transient combined salinity and water stress, Agric. Water Management, 57, 127-144 7. De Jong van Lier, Q., D. Dourado Neto, and K. Metselaar (2008). Modeling of transpiration reduction in van Genuchten-Mualem type soils, Water Resour. Res., 45, W02422, doi:10.1029/2008WR006938 8. Corwin, D.L., J. Hopmans, and G.H. de Rooij. (2006). From field- to landscape-scale vadose zone processes: scale issues, modeling, and monitoring. Vadose Zone Journal 5:129-139. doi:10.2136/vzj2006.004. 9. Van der Zee, S.E.A.T.M., Janssen, G.M.C.M., and R.C. Acharya (2004). Upscaling biogeochemically reactive chemical transport, in: Saturated and Unsaturated Zone, Integration of Process Knowledge into Effective Models, La Goliardica Pavese, Pavia, 355-362, 2004

nr 3 Track record research group	
Name research group	KWR Watercycle Research Institute
Research Profile	KWR is the Dutch research and knowledge institute for the entire water cycle, covering the fields of water supply, sanitation, and water management.
Main research themes	KWR's research covers science domains like protection of catchment areas, production and supply of drinking water, human health, and wastewater collection and treatment. All water-related disciplines are present at KWR, including hydrology, ecology, toxicology, geochemistry, microbiology, chemical technology, distribution technology, and knowledge management. Three of the big research themes are: artificial recharge, a climate-proof and environmental-friendly water sector, and preparing fresh water from brackish groundwater via reverse osmosis.
Main scientific achievements	If we focus on the Water Systems Department of KWR, the following achievements deserve highlighting: • Quantification of feedbacks between water, climate and vegetation (Kruit et al., 2008; Witte et al. 2008) • Development of predictive eco-hydrological models for vegetation targets (PROBE, WATERNOOD) • Development of Menyanthes, a tool for analyzing groundwater level time series (www.menyanthes.nl) • Development of RESPOND, a tool for risk assessment of groundwater quality (Vink, 2006) • Development of EASY-LEACHER, INFOMI and REACTIONS+, (reactive) transport models for artificial recharge systems (Stuyfzand, 1998 • Development of the fresh-keeper principle and fresh water supply via brackish water reverse osmosis in the Netherlands (Stuyfzand & Raat, in press).
10 key publications	1. Bakker, M., K. Maas, F. Schaars & J. R. von Asmuth, 2007. Analytic modeling of groundwater dynamics with an approximate impulse response function for areal recharge. *Advances in Water Resources* 30: 493-504. 2. Cornelissen, E.R., N. Moreau, W.G. Siegers, A.J. Abrahamse, L.C. Rietveld, A. Grefte, M. Dignum, G. Amy & L.P. Wessels, 2008. Selection of anionic exchange resins for removal of natural organic matter (NOM) fractions. *Water Research* 42: 413-423. 3. Hijnen, W.A.M., D. Biraud, E. R. Cornelissen & D. van der Kooij, 2009. Threshold Concentration of Easily Assimilable Organic Carbon in Feedwater for Biofouling of Spiral-Wound Membranes. *Environmental Science & Technology* 43: 4890–4895. 4. Maas, K., 2007. Influence of climate change on a Ghijben-Herzberg lens. *Journal of Hydrology* 347: 223-228. 5. Meuleman, A.F.M., G. Cirkel & J.J.G. Zwolsman, 2007. When Climate change is a fact! Adaptive strategies for drinking water production in a changing natural environment. *Water Science & Technology* 56: 137-144. 6. Van der Wielen, P.W.J.J., W.J.M.K. Senden & G. Medema, 2008. Removal of Bacteriophages MS2 and ΦX174 during Transport in a Sandy Anoxic Aquifer. *Environmental Science & Technology* 42: 4589–4594. 7. Van Vliet, M.T.H. & J.J.G. Zwolsman, 2008. Impact of summer droughts on the water quality of the Meuse River. *Journal of Hydrology* 353: 1-17. 8. Vink, C., 2006. *Application of heuristic optimisation techniques for spatial environmental problems with multiple objectives.* Thesis, Utrecht University. 9. Stuyfzand, P.J. & K.J. Raat in press. Benefits and hurdles of using brackish groundwater as a drinking water source in the Netherlands. Hydrogeol. J. 2010,

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	DOI: 10.1007/s10040-009-0527-y. 10. Stuyfzand, P.J. 1998. Simple models for reactive transport of pollutants and main constituents during artificial recharge and bank filtration. In: Peters J.H. (ed), Artificial recharge of groundwater, Proc. 3rd Intern. Symp. on Artificial Recharge, Amsterdam the Netherlands, Balkema, 427-434.

nr 4 Track record research group	
Name research group	VU University Amsterdam, Department of Hydrology and Geo-Environmental Sciences , Faculty of Earth and Life Sciences
Research Profile	The Faculty of Earth and Life Sciences was established in September 2001 as a result of a merger of the Faculties of Earth Sciences and Biology and the Institute for Environmental Studies. The environmental research includes research on physical processes related to water resources, groundwater, geohydrology and ecological systems, the impact of land use change on our climate, geomorphology, biodiversity, carbon and nutrient cycling, as well as research on the social and economic issues. The Department of Hydrology and Geo-Environmental Sciences has over 30 years of experience in the research of hydrologic systems in the Netherlands and abroad and coastal aquifers in particular.
Main research themes	The department focuses its research on the analysis and synthesis of hydrological systems in order to enhance both qualitative and quantitative understanding of groundwater processes and conditions. Its main research themes include: • Salinisation of surface water and shallow groundwater in coastal lowlands • Natural background quality of groundwater and effects of diffuse pollution • Occurrence and fate of pollutants • Impacts of climate change and changes in land use on groundwater composition and thermal regimes • Managed aquifer recharge (MAR) and subsurface storage
Main scientific achievements	The main scientific achievements of the group are in the fields of: • Identification of rates and patterns of salinisation during vertical sea-water intrusion in field, laboratory and modelling studies • Co-development of the PHT3D code for reactive transport modelling • Development of models for using temperature as a tracer in groundwater studies • Modelling of osmotically-driven flow and transport in clayey sediments
10 key publications	1. Post, V.E.A. & C.T. Simmons (2009). Free convective controls on sequestration of salts into low-permeability strata: insights from sand tank laboratory experiments and numerical modelling. Hydrogeology Journal DOI 10.1007/s10040-009-0521-4 2. Post, V.E.A. & H. Prommer (2007). Multicomponent reactive transport simulation of the Elder problem: effects of chemical reactions on salt plume development. Water Resources Research 43(10), DOI W1040410.1029/2006WR005630 3. Post, V.E.A., H. Kooi, C.T. Simmons (2007). Using Hydraulic Head Measurements in Variable-Density Ground Water Flow Analyses. Ground Water: DOI 10.1111/j.1745-6584.2007.00339.x 4. Post, V.E.A. (2005). Fresh and saline groundwater interaction in coastal aquifers: is our technology ready for the problems ahead? Hydrogeology Journal 13(1): DOI 10.1007/s10040-004-0417-2 5. Green, R.T., M. Taniguchi and H. Kooi (2007) Potential Impacts of Climate Change and Human Activity on Subsurface Water Resources, preface to special issue, Vadose Zone Journal, 6: 531-532, doi:10.2136/vzj2007.0098 6. Groen, M., Kok, A., Van der Made, K. J. & Post, V. E. A. (2008). The Use of Mapping the Salinity Distribution Using Geophysics on the Island of Terschelling for Groundwater Model Calibration. Proceedings of the 20th Salt Water Intrusion Meeting, Naples, Florida, 23-27 June 2008 p. 124-127 7. Kooi, H. (2008). Spatial variability in subsurface warming over the last three decades; insight from repeated borehole temperature measurements in The Netherlands. Earth and Planetary Science Letters, 270, 86-94.

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nr 5 Track record research group	
Name research group	VU University Amsterdam, Dept of Systems Ecology, Institute of Ecological Science
Research Profile	The department of Systems Ecology studies how climate change affects the interactions between vegetation, soil, hydrosphere and atmosphere using a systems ecological approach. We do this by: -Applying the results of our fundamental research to areas where society needs sound and robust answers to environmental problems (*e.g. salinisation, sea level rise and coastal defense, spatial planning*). -Focusing on cold and cool biomes (including NW-Europe) using an experimental approach both in the field, experimental gardens and climate rooms. -Performing long-term field experiments, using functional traits as the basis for our response and effect parameters. -Making projections of future ecosystem behavior based on the results obtained today and from the past both by experimentation and modelling at various spatial and temporal scales.
Main research themes	The main theme is the relation between climate change, biodiversity and ecosystem functioning. In addition to that we focus on: -The impact of extreme events on ecosystem functioning -Climate change, coastal defense, spatial planning, and ecology -The ecological impacts of changing water availability due to climate change.
Main scientific achievements	The department is one of the key groups within the Darwin Center for Biogeology. We participate in and partly coordinate international networks conducting meta-analyses of key ecological questions at the biome or global scale (Glopnet, International Tundra Experiment, GCTE Functional Types Network, EC network Putting *Halophytes* to Work - From Genes to Ecosystems, Meeting of Litters, TRY, LPJ, TERRABITES). As a result of all these activities, we are considered to be one of the leading ecological groups in climate change research in cold biomes as is apparent from our publications (see below) and the number of times the work of the group is cited. During the most recent QUANU endorsed research evaluation (2008) the group was rated *'Excellent'* for both Quality, Productivity and Viability
10 key publications	1. Rozema, J., van Geel, B., Björn, L.O., Lean J., Madronich, S. (2002). Toward solving the UV puzzle. Science 296: 1621-1622. 2. Rozema, J., Flowers, T. (2008). Crops for a salinized world. Science 322: 1478-1480. 3. J.Rozema, J., Aerts, R., Cornelissen, H. (2006). Plants and climate change. Springer, Dordrecht 4. Wright, I.J., P.B. Reich, M.Westoby, D.D. Ackerly, Z. Baruch, F. Bongers, J. Cavendar-Bares, T. Chapin, J.H.C. Cornelissen *et al.* (2004). The worldwide leaf economics spectrum. Nature 428: 821-827. 5. Bodegom, P.M. van, Oosthoek, A., Broekman, R., Bakker, C., Aerts, R. (2006). Raising groundwater differentially affects mineralization and plant species abundance in dune slacks. Ecological Applications 16:1785-1795. 6. Cornelissen, J.H.C., van Bodegom, P.M., Aerts, R., and many others (2007). Global negative vegetation feedback to climate warming responses of leaf litter decomposition rates in cold biomes. Ecology Letters 10:619-627. 7. Cornwell, W.K., Cornelissen, J.H.C., Amatangelo, K., Dorrepaal, E., Eviner, V.T., Godoy, O., Hobbie, S.E., Hoorens, B., Kurokaw, H., Perez Harguindeguy, H., Quested, H.M., Santiago, L.S., Wardle, D.A., Wright, I.J., Aerts, R., Allison, S., van Bodegom, P.M., and many others (2008). Plant species traits are the predominant control on litter decomposition rates within biomes worldwide.

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	Ecology Letters 11:1065-1071. 8. DeDeyn, G.B., Cornelissen J.H.C., Bardgett R.D. (2008). Plant functional traits and soil carbon sequestration in contrasting biomes. Ecology Letters 11: 516-531. 9. Suding, K.N., Lavorel, S. Chapin III F.S., Cornelissen J.H.C., Díaz S., Garnier E., Goldberg D., Hooper D.U., Jackson S.T., Navas M.L. (2008). Scaling environmental change from traits to communities to ecosystems: the challenge of complexity at intermediate scales. Global Change Biology 14: 1-16. 10. Weedon, J.T., Cornwell W.K., Cornelissen J.H.C., Zanne A.E., Wirth C., Coomes D.A. (2009). Global meta-analysis of wood decomposition rates: a role for trait variation among tree species? Ecology Letters, 12: 45-56.

nr 6 Track record research group	
Name research group	University of Twente – Water Engineering and Management
Research Profile	The research group Water Engineering and Management is part of the Twente Water Centre (TWC). TWC is a centre of expertise in the area of water systems and governance. The Centre is unique in bringing together and balancing the natural and social sciences. Thereto the Centre bundles expertise from various groups located within the University of Twente and the International Institute for Geo-Information Science and Earth Observation (ITC). The focus of the research of the group Water Engineering and Management is on water systems and policy analysis.
Main research themes	The Twente Water Centre has four main research themes: - river and marine science and engineering - water systems and policy analysis - water governance - uncertainty and risk analysis The first theme focuses on the understanding of the physical processes in large surface water bodies such as rivers, estuaries and seas. In the second theme, interactions between human and natural processes are studied within the framework of systems theory and policy is studied from a policy analytical point of view, focused on policy instruments and their effects rather than on policy processes. The theme of water governance focuses on the study of policy processes, institutional arrangements and networks. The theme of uncertainties and risk analysis is cross-cutting and addresses the role of uncertainties and risks in both systems understanding and policy making. The focus of the Water Engineering and Management group is on the 2nd research theme but in carrying you its activities is closely collaborates with in particular the 3rd and 4th research theme.
Main scientific achievements	Some important scientific achievements of the group are: - developing scientific foundation on the water footprint approach - agent based modelling of water resources issues under extreme conditions (a.o. due to climate change) - integration of spatial planning and water resources management - appropriate modelling in decision support systems
10 key publications	1. Beek, E. van. (2009). Managing Water under Current Climate Variability, chapter in book 'Climate Change Adaptation in the Water Sector', edited by F. Ludwig, P. Kabat, H. van Schaik and M. van der Valk, Earthscan, UK 2. Beek, E. van, Bozorgy, B, Vekerdy, Z, Meijer, K.S. (2008). Limits to agricultural growth in the Sistan Closed Inland Delta, Iran, Irrigation and Drainage System (2008) 22:131–143, Springer. 3. Filatova, T., Parker, D. and van der Veen, A. (2009). Agent - based urban land markets : agent's pricing behavior, land prices and urban land use change. In: Journal of Artificial Societies and Social Simulation, 12(1009)1, paper. 3. 31 p. 4. Haasnoot, M; Middelkoop, H.; Beek, E. van; Deursen, W.P.A. van (2009). A method to develop sustainable water management strategies for an uncertain future, Accepted for publication in Sustainable Development, Wiley 5. Hoekstra, A.Y. (2009). Water security of nations: How international trade affects national water scarcity and dependency, In: Jones, J.A.A., Vardanian, T.G. and Hakopian, C., Threats to global water security, NATO Science for Peace and Security Series C: Environmental Security, Springer, Berlin, pp. 27-36 6. Hoekstra, A.Y. and Chapagain, A.K. (2007). Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK. 7. Kolkman, M.J., van der Veen, A. and Geurts, P.A.T.M. (2007). Controversies in

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	water management: frames and mental models. In: Environmental impact assessment review, 27 (2007)7, pp. 658-706. 8. Loucks, D.P; Beek, E. van. (2005). Water Resources Systems Planning and Management – an introduction to methods, models and applications (600 page text book, December 2005, UNESCO – Paris 9. Offermans, A; Valkering, P;, Haasnoot, M, Beek, E. van; Middelkoop, H. (2008). Advies van de Deltacommissie vraagt breder perspectief (in Dutch), H2O / 20 October 2008 10. van der Veen, A. and Logtmeijer, C. (2005). Economic hotspots : visualizing vulnerability to flooding. In: Natural hazards : journal of the international society for the prevention and mitigation of natural hazards, 36 (2005)1-2, pp. 65-80.

nr 7 Track record research group	
Name research group	Alterra, Earth System Science and Climate Change Group Wageningen University and Research Centre, Environmental Sciences Group
Research Profile	Wageningen University and Research Centre (Wageningen UR) is a cluster of internationally-leading knowledge institutions providing education and scientific and applied knowledge in the field of life sciences and natural resources. The Environmental Science Group (ESG) of Wageningen UR is formed by Alterra and 21 Chair groups of Wageningen University and focuses on four main topics: rural development, biodiversity and ecosystem services, climate change and adaptation, and risk management. Alterra conducts fundamental and applied research on a variety of interrelated themes such as integrated water management, climatic effects on flooding and drought, uptake, emission and transport of pollutants such as greenhouse gases, nutrients, chloride and pesticides. Other research topics are restoration and management of aquatic ecosystems. Our expertise related to this research proposal especially concentrates on: • Environmental, Agro- and Ecosystems Hydrology • Crop Production in relation with Soil and Water Salinity • Climate change adaptation Two chairs of Wageningen University, and Alterra teams of the Environmental Science Group (ESG) are involved: Department Earth System Science and Climate Change (ESS-CC prof. Pavel Kabat) and Alterra teams, Integral Water Management (IW) and Integrated Water Resources Management (IWRM), Department Soil Physics, Ecohydrology, and Groundwater Management (SEG prof. Sjoerd van der Zee) of the Centre for Water and Climate, team Ecological Modelling and Monitoring (EMM) of the Centre for Landscape.
Main research themes	The mission of ESS-CC is to advance our understanding of the Earth and Climate System as a complex system, with specific inclusion of the anthropogenic components. Properties and processes of the components of the Earth System, such as carbon or water cycles in the terrestrial and atmospheric compartments, are investigated as integral parts of the system on regional and global scales, focusing on their interactions and feedbacks. The ESS-CC Group includes the following research themes: **1. Adaptation strategies:** the group applies and communicates knowledge, supporting governments and stakeholders in the development of adaptation strategies to climate change for rural and urban delta's. **2. Land Atmosphere Interactions:** The group studies bio-geochemical processes, the cycling of substances through the different reservoirs (soil, water, and atmosphere), and the influence of climate change on these processes. **3. Regional and Global Scale Interactions of Land Use, Hydrology and Climate:** This cluster brings together a unique group of hydrologist, meteorologists, biologists and agricultural scientist studying the relationships between climate (change), land use and water. **4. Human Dimension of climate change:** The main focus of the group is on the interactions between society and scientific research, in order to improve the practical applicability of knowledge and innovations with respect to Earth System Science.
Main scientific achievements	ESS-CC has a leading role in EU funded research projects, such as HighNoon and WATCH, and coordinates scientifically in two major national climate research programs'Climate changes Spatial Planning' and 'Knowledge for Climate'. Other important programs, which ESS-CC contributes to are the Wadden Academy and Delta Alliance. A recent bibliometric analysis (2007) showed that over 1996 until 2006, the relative impact of the publications was far above world average (2.83 compared to world average of 1.0). 39 out of 108 analyzed A-category journal publications belonged to the 10% highest cited publications; this is 36% of total publications. The h index was 22.

nr 7 Track record research group	
10 key publications	1. Ludwig F., Kabat P., Schaik H. van, Valk M. van der, (2009). Climate change adaptation in the water sector. Earthscan, London. 2. Kabat, P., Vellinga, P., Aerts, J., Veraart, J., and W. van Vierssen, W., (2005). Climate Proofing The Netherlands. Nature, 438, 283-284 3. Kabat, P., L.O. Fresco, M.J.F. Stive, C.P. Veerman, J.S.L.J. van Alphen, B Parmet, W.Hazeleger and C.A. Katsman (2009). Dutch coasts in transition, *Nature Geoscience ,* 2, 450-452 *4.* Maat, H.W. ter; Franssen, W.H.P., Hurkmans, R.T.W.L.. Terink, W., Tuinenburg, O.A., Moors, E.J. (2008). Climate change-driven adaptation measures in a coupled hydrological-atmospheric mode**l** *In: Proceedings of the Annual Meeting of the European Meteorological Society, 29 September - 3 October, 2008, Amsterdam, The Netherlands.* 5. Kabat, P, Schulze, R.E. Hellmuth, M.E., Veraart, J.A. and Lenton, R. (2003). Climate Variability and Change and Freshwater Water Management. International Review for Environmental Strategies 3: 294-302. 6. Werners, S. E., Z. Flachner, P. Matczak, M. Falaleeva and R. Leemans (2009). Exploring earth system governance: a case study of floodplain management along the Tisza River in Hungary. Global Environmental Change (accepted). 7. Kabat, P., M. Claussen, P.A. Diemeyer, J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R. A. Pielke Sr., Ch.J. Vorosmarty, R.W.A. Hutjes and S. Lutkemeier, (eds) (2004). Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System. Springer Verlag, Berlin/New York; 566 p, ISBN 3540424008 8. Swart, R., L. Bernstein, M-H Duong and A. Petersen (2009). Agreeing to disagree: Uncertainty management in assessing climate change, impacts and responses by the IPCC, Climatic Change 92(1-2):pp 1-29 9. Jiggins J. E., Van Slobbe, N. Röling. (2007). "The Organisation of Social Learning in Response to Perceptions of Crisis in the Water Sector of the Netherlands." Environmental Science & Policy 10(6): 526-536. 10. Veraart J.A., Groot R.S. de, Perello G., Riddiford N.J., Roijackers R.M.M. (2004). Selection of (bio)indicators to assess effects of freshwater use in wetlands a case study of s'Albufera de Mallorca, Spain. Regional Environmental Change.Volume 4, Numbers 2-3,pp 107 - 117.

nr 8 Track record research group	
Name research group	Delft University of Technology, Policy Analysis group, Faculty Technology, Policy and Management
Research Profile	The research of the TU Delft Faculty of Technology, Policy and Management (TPM) concentrates on the design and management of complex systems in which both technology and social and institutional elements are present and cannot be considered separately when trying to understand and govern the functioning of the system as a whole. The research is applied in particular to infrastructure systems (ICT, transport, Energy, Water). The two largest research programmes of the faculty concentrate on Multi Actor Systems, and Infrastructure Systems, respectively. The Policy Analysis research group is part of the Multi-Actor Systems programme. This programme develops theories about and methods for interventions in multi-actor systems, combining perspectives from the social and policy sciences ('the actor perspective') on the one hand, and from the engineering and system sciences ('the system perspective') on the other. The Policy Analysis group, consisting of about 20 fte, focuses in particular on the development and testing of approaches, methods and techniques to support the resolution of complex policy issues in multi-actor contexts. While most of the staff have their disciplinary roots in the engineering and/or natural sciences, research explicitly concentrates on the application of systemic methods in multi-actor contexts. External funding sources include NWO, several national BSIK programmes, government institutions, and utility companies.
Main research themes	Within the broad and varied field of Policy Analysis, the TPM group concentrates in particular on the following themes: - theory-building and conceptualization of policy analysis as a craft that uses a variety of approaches and combinations of methods - embedding the use of analytic methods such as modelling and simulation, multicriteria analysis, etc., in multi-actor policy processes - methods for the modelling and analysis of actors, actor interactions, and actor networks - uncertainties: conceptualization, analytic approaches, and policy strategies in light of uncertainties - modelling of transitions. Application fields include water management and spatial planning (over 50% of the group's research is in this field), energy (about 20%), transport(15%) and general sustainability issues.
Main scientific achievements	The Policy analysis group co-leads and contributes an important core to the faculty programme 'Multi-Actor Systems' that was evaluated as very good (4.5 out of 5) and of international standing in the last formal VSNU evaluation. The group has recently lead a key NWO progamme on dealing with uncertainties in energy transitions, and participates in several national BSIK programmes, including Next generation Infrastructures, Living with Water, Delft Cluster, and Knowledge and System Innovation. As illustrated by its publication record, the group provides internationally leading contributions in its specialization fields, such as actor/network analysis methods, uncertainty analysis and adaptive policy design, and policy analysis in general.
10 key publications	1. Walker W.E. (2000).Policy Analysis: A Systematic Approach to Supporting Policymaking in the Public Sector, Journal of Multi-Criteria Decision Analysis, 9, 1-3, p. 11-27. 2. Walker, W.E. , Harremoes, P. , Rotmans, J. , Sluijs, J.P. van der, Asselt, M.B.A. van, Janssen, P. Krayer von Kraus, M.P. (2003). Defining Uncertainty. A

nr 8 Track record research group	
	conceptual Basis for Uncertainty Management in Model_based Decision Support. Integrated Assessment, 4(1), 5-17. 3. Hermans, L.M., Beroggi, G.E.G. and Loucks, D.P. (2003). Managing water quality in a New York City watershed. Journal of Hydroinformatics, 5(3), 155-168. 4. Mayer, I.S., Daalen, C. van, and Bots, P.W.G. (2004). Perspectives on policy analyses: a framework for understanding and design. International Journal of Technology, Policy and Management 4 (2), 169-191. 5. Hermans, L.M., Halsema, G.E. van, and Mahoo, H.F. (2006). Building a mosaic of values to support local water resources management. Water Policy, 8, 415-434. 6. Karstens, S., Bots, P.W., and Slinger, J.H. (2007). Spatial boundary choice and the views of different actors. Environmental impact assessment review, 27(5), 386-407. 7. Slinger, J.H., Muller, M. and Hendriks, M. (2007). Exploring local knowledge of the flooding risk of the Scheldt Estuary. Water science and technology, 56(4), 79-86. 8. Vreugdenhil, H.S.I., Slinger, J.H. and Kater, E. (2007). Adapting scale use for successful implementation of Cyclic Floodplain Rejuvenation in the Netherlands. In C. Pahl-Wostl, P. Kabat & J. Möltgen (Eds.), Adaptive and Integrated Water Management (pp. 301-321). Berlin: Springer. 9. Hermans, L.M. (2008). Exploring the Promise of Actor Analysis for Environmental Policy Analysis: Lessons from Four Cases in Water Resources Management. Ecology and society, 13(1), 1-16. 10. Bots, P.W.G. and C. van Daalen (2008). Participatory model construction and model use in natural resource management: a framework for reflection. Systemic practice and action research, 21(6), 389-407.

nr 9 Track record research group	
Name research group	Acacia Water
Research Profile	Acacia Water "for solutions in groundwater" was established in 2003 at the Vrije Universiteit Amsterdam (Faculty of Earth and Life Sciences). Acacia Water provides groundwater advice in relation to surface water, environment and infrastructure. This varies from implementation of field measurements and model calculations, to provision of training and strategic advice. The strength of Acacia Water is the specialization in the field of groundwater, while at the same time being able to place issues in a broader perspective and to link up with other professions and fields of action. As a result we will often work in a multidisciplinary environment with a broad variety of expertise. As a network organization, Acacia does not attempt to offer all specialties in house, but instead forms alliances with individual experts and specialized organizations and companies. Our expertise focus on groundwater technology, groundwater-management, project-management, knowledge exchange (including training) and product development and innovations. Acacia employs 9 people of whom 4 are senior groundwater assessment, development and management experts with a broad experience, both in the Netherlands and abroad. Although Acacia operates as consultancy firm their projects are very innovative and through its strong links with the VUA and the organizations active in water management, the company bridges the gap between research and market.
Main research themes	*Salinisation and fresh water supply* In coastal lowlands, salt water intrusion and upwelling of brackish groundwater increases due to climate change. In order to adapt to these changes in water quality, the change in available fresh water and to identify a set of potential measures, understanding is required of the physical aspects of salt transport in the groundwater at different spatial and temporal scales. For policy and decision making it is important to know to what extent the current and future salinisation will take place. *Recharge, retention and reuse (3R)* Acacia Water has taken the initiative to actively study and promote the storage of excess water in the underground during wet periods and the reuse during periods of drought. Through projects and other initiatives we are actively researching and promoting 3R in countries such as Ethiopia, Kenya, Ghana, Botswanan and Zimbabwe. We are linking this initiative to experiences in the Netherlands
Main scientific achievements	Acacia Water actively involved in a number of hydrological studies in the polders of the western Netherlands (Groot Mijdrecht, Bijlmermeer, Schermer, Wieringermeer). These studies are part of PhD studies of the Acacia researchers Jouke Velstra (ongoing) and Koos Groen at the VU Amsterdam (Groen et al, 2000; Groen, 2002, Post et al, 2001). The focus is on groundwater seepage and salinity and the interaction of groundwater with superficial runoff from agricultural and urban areas. A variety of techniques have been applied from drilling, cone penetration tests, surface and airborne geophysics, small weirs and divers. Investigating the more detailed spatial and temporal variations in discharges, water levels and salinities has provided new scientific insight into the hydrological processes of our polders (2009 in preparation). This insight is necessary for fine-tuning drainage, storage and water supply measures and ultimately increasing the self-reliance of the polder systems (Velstra et al, 2009, Velstra en de Vries, 2008). Acacia Water also studied the salinization of coastal waters in Suriname (Groen, 2002) and Bonaire and saline waste lands in India. The latter was part of a large EU funded project dealing with adaptation by applying biosaline agroforestry. Underground storage of water, like in sand dams, has become a key issue in increasing rural water supply in the third world (Lasage et al, 2008; Tuinhof, 2003). Also in the Netherlands groundwater storage by adapting drainage systems and variable polder levels is crucial in moderating discharge and water quality variations of surface water.

nr 9 Track record research group	
10 key publications	1. De Vries, A.C. et. al., 2009, Vraag en aanbod van zoetwater in the Zuidwestelijke Delta, KVK rapport KVK017/09. 2. Groen, J., 2002. The effects of transgressions and regressions on coastal and offshore groundwater. Ph.D. Thesis Vrije Universiteit Amsterdam, pp 192. 3. Groen, J., Velstra, J. and Meesters, A.G.C.A., 2000. Salinization processes in paleowaters in coastal sediments of Suriname: evidence from δ37Cl analysis and diffusion modeling. Journal of Hydrology 234, 1-20. 4. Lasage, R., J. Aerts, G.-C.M. Mutiso, A.C. de Vries, 2008. Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya, Physics and Chemistry of the Earth 33; 67–73 5. Tuinhof, A. et.al. 2003. Recharge enhancement and sub surface storage: a promising option to cope with increasing storage needs. Management of Aquifer Recharge, NCC-IAH publication no.4, Utrecht, The Netherlands 6. Velstra, J. and M. ter Voorde, 2009, Leven met Zout Water: Overzicht huidige kennis omtrent interne verzilting, STOWA report 2009-45. Velstra, J., J. Groen, J.J. de Vries, 2009. The impact of drainage systems on the occurrence of freshwater lenses. In preparation. 7. Velstra, J. en A.C. de Vries, 2008. Nieuwe kijk op verzilting biedt perspectief voor zoetwatertekort, H2O - 18, p22- 23. 8. Velstra, J., M. Hoogmoed and J. Groen, 2009. Leven met Zout Water, deelrapport: Inventarisatie maatregelen omtrent interne verzilting, Acacia Water 9. Velstra, J., R. van Diepen, M. Hoogmoed, J. Groen and M. Groen, 2008. Aanvullend veldonderzoek Groot Mijdrecht Noord, Acacia Rapport

nr 10 Track record research group	
Name research group	Utrecht University, Faculty of Science, Division Science, Technology and Society
Research Profile	STS was created January 1988 bringing together the sections 'Chemistry & Society', 'Physics & Society', and 'Biology & Society' (created in 1975/1976) in one group. STS is nowadays part of the dept. of Chemistry, which is part of the Faculty of Science. STS is also part of the UU Copernicus Institute for Sustainable Development and Innovation. The mission of STS regarding research is to develop and transfer knowledge, skills and excellence in the fields of sustainable energy and materials consumption and production systems, land use and biodiversity, management of ecological risks and uncertainties, and the transformation of economies towards sustainability'. The ambition of STS is to make a difference (in science, society and education) in achieving a now role for science and technology contributing to sustainable development'.
Main research themes	The research programme of STS is clustered around three themes: - Energy and Materials Demand and Efficiency - Energy Supply and System Studies - Energy and Global Change: Dealing with Risks and Uncertainties The present proposal fits in the third cluster, which aims at conceptual work on development and application of methodologies and approaches that facilitate a better management of uncertainty in the science-policy interface. We focus on those situations where scientific assessment is used as a basis for policy making on environmental risks, before conclusive scientific evidence and scientific consensus are available on the causal relationships, the magnitude and the probabilities of these risks. Policy decisions on such risks (e.g. climate change adaptation) cannot wait until the scientific understanding is complete, thus the knowledge base available for decision making is unavoidably incomplete, controversial and uncertain. This poses high demands on the ways uncertainties and dissent are dealt with in scientific assessment and how these are communicated to policy makers and society. It also requires robust and flexible policy strategies that can accommodate uncertainty. The programme objectives are: • Theory development on uncertainty in science for policy; • Developing, demonstrating, and applying methods, instruments and strategies for uncertainty management, uncertainty communication, quality control, and extended peer involvement.; • Development of policy strategies under uncertainty (robust decision making, resilience, flexibility, precautionary principle).
Main scientific achievements	Based on external peer review: - High international recognition - High ISI WoS citation index ("RI far above average" – above 1.6). - High external funding rate: about 75% of research is funded from external sources (20% NWO; 55% contract research). - Many invitations for lectures, membership of scientific boards and of programme, steering, evaluation and advisory committees, (Convening) Lead Authorships (IPCC assessments, WEA, IEA-WEO, GEA, UNESCO report on Precautionary Principle), editorships, professorships. Relevant achievements for this proposal include: - Operationalization of resilience as a strategy for climate change adaptation under uncertainty; - Development, demonstration and testing of the NUSAP method for multidimensional uncertainty assessment - Empirical research on the communication of uncertainties in environmental assessments to non-scientific audiences in the science-policy interface. - Development demonstration and testing of a checklist for model quality assistance and a checklist for state of the art uncertainty assessment and communication for the

nr 10 Track record research group	
	Netherlands Environmental Assessment Agency
10 key publications	1. J.A. Wardekker, A. de Jong, J.M. Knoop and J.P. van der Sluijs (in press), Operationalising a resilience approach to adapting an urban delta to uncertain climate changes, Technological Forecasting and Social Change special issue on adaptive policies. (doi: 10.1016/j.techfore.2009.11.005) 2. J.P. van der Sluijs, A.C. Petersen, P.H.M. Janssen, James S Risbey and Jerome R. Ravetz (2008) Exploring the quality of evidence for complex and contested policy decisions, Environmental Research Letters, 3 024008 (9pp) (doi: 10.1088/1748-9326/3/2/024008) 3. S. Dessai and J.P. van der Sluijs, 2007, Uncertainty and Climate Change Adaptation - a Scoping Study, report NWS-E-2007-198, Department of Science Technology and Society, Copernicus Institute, Utrecht University. 95 pp. 4. J.A. Wardekker, J.P. van der Sluijs, P.H.M. Janssen, P. Kloprogge, A.C. Petersen, (2008). Uncertainty Communication in Environmental Assessments: Views from the Dutch Science-Policy Interface, Environmental Science and policy, 11, 627-641. (doi: 10.1016/j.envsci.2008.05.005) 5. J-C. Refsgaard; J.P. van der Sluijs; A.L. Højberg; P.A Vanrolleghem (2007), Uncertainty in the environmental modelling process: A framework and guidance, Environmental Modelling & Software, 22 (11), 1543-1556. (doi: 0.1016/j.envsoft.2007.02.004) 6. J.P. van der Sluijs (2007), Uncertainty and Precaution in Environmental Management: Insights from the UPEM conference, Environmental Modelling & Software, 22, (5), 590-598. (doi: 10.1016/j.envsoft.2005.12.020) 7. J-C. Refsgaard, J.P. van der Sluijs, J. Brown and P. van der Keur (2006), A Framework For Dealing With Uncertainty Due To Model Structure Error, Advances in Water Resources, 29 (11) 1586–1597. (doi: 10.1016/j.advwatres.2005.11.013) 8. P. Kloprogge and J.P. van der Sluijs (2006), The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Climatic Change, 75 (3) 359-389. (doi: 10.1007/s10584-006-0362-2) 9. J.P. van der Sluijs, M. Craye, S. Funtowicz, P. Kloprogge, J. Ravetz, and J. Risbey (2005), Combining Quantitative and Qualitative Measures of Uncertainty in Model based Environmental Assessment: the NUSAP System, Risk Analysis, 25 (2). p. 481-492 (doi: 10.1111/j.1539-6924.2005.00604.x) 10. W.E. Walker, P. Harremoës, J. Rotmans, J.P. van der Sluijs, M.B.A. van Asselt, P. Janssen, and M.P. Krayer von Krauss (2003), Defining Uncertainty A Conceptual Basis for Uncertainty Management in Model-Based Decision Support, Integrated Assessment, 4 (1), 5-17.

nr 11 Track record research group	
Name research group	TNO Built Environment and Geosciences, Group Water Treatment
Research Profile	The Netherlands Organisation for Applied Scientific Research (TNO) is the largest fully independent nonprofit research organization in the Netherlands. TNO's public mission is to support industry and society in general in transforming knowledge into products and processes of economic and societal value. Within the department of Water Treatment Technology of TNO Built Environment and Geosciences innovative water treatment technologies are developed in cooperation with end users and technology suppliers. Also consultancy in the area of Industrial Water Management and water treatment are carried out. TNO is closely involved in the EU Water Supply and Sanitation Technology Platform (WSSTP) (board member) , and is secretary of the Pilot Advisory group 'Sustainable Water use in Industry. TNO disposes of excellent laboratory and pilot facilities, under several for membrane processes, crystallization, adsorption and different hybrid processes. A number of new water treatment technologies are under development, like Memstill, FACT (Filtration aided Crystallization Technology), MDC (membrane distillation-Crystallization) and MBA (Moving Bed Adsorption). Besides TNO is also able to combine the Water knowledge with knowledge of processes and products from different sectors, where the different departments of TNO are focusing at (Food, Chemistry etc.).
Main research themes	TNO contributes to sustainable solutions for this problem through: • the development and application of technologies to treat water • the development and application of entirely new water systems and concepts Three themes are central to this: water and health, water and reuse and water and energy. TNO approaches water issues through combining membrane technology, microbiology and electro chemistry. We work closely with universities, suppliers, equipment builders, system suppliers, and end users to implement new technology and also with the authorities to implement new process concepts. TNO Water treatment has 10 patents. Water re-use in industry is often an elegant way to reduce water consumption. Waste water of high quality forms an excellent method to optimize water chains. Water recycling often leads to energy and cost savings. This is especially true for hot or cold water streams. TNO gives special attention to components that can recycle without being removed, like persistent organic compounds. Depending on the nature of the contaminants, these can be selectively removed. To lower the cost of water treatment, standardization in process water quality is proposed by TNO. A very specific waste stream for recycling is the membrane retentate produced in the desalination of sea or surface water. Energy efficient dewatering by membrane distillation can lead to low cost crystallizing salt products. Sea water desalination is regarded world-wide a very promising technology to provide water to the growing world population at a reasonable cost. Currently, the total desalination volume increases with 25 percent annually. Desalination will also become important for treating industrial waste water that contains more salt than is allowed by the new European framework directive water. This directive is to be implemented in the coming years.

nr 11 Track record research group	
	TNO develops new technologies to enable low cost water desalination: • Membrane distillation with Memstill; a technology that uses (low cost) waste heat. • Membrane distillation with solar heat for decentralized production of potable water. Rural communities, resorts and remote islands may benefit from this idea. • Electro-dialysis separates salt ions from water and enables the formation of acids and bases from salt solutions. • Eutectic freezing, a special form of freeze crystallization yields pure water and salt crystals, allowing the disposal of solid salt.
Main scientific achievements	See above
10 key publications	1. J.H. Hanemaaijer et al., Method for the purification of a liquid by Membrane Distillation in particular for the production of desalinated water from seawater or brackish water or process water, 2004, US6716355 2. J.H. Hanemaaijer et al., Membrane Distillation method for the purification of a liquid, 2009, EP2094376 3. J.H. Hanemaaijer, J. van Medevoort, A.E. Jansen, C. Dotremont, E. van Sonsbeek, Tao Yuan, L. De Ryck, Memstill membrane distillation – a future desalination technology, Desalination 199, 175–176 (2006) 4. J.T.M. Sluys, D. Verdoes, J.H. Hanemaaijer, Water treatment in a Membrane-Assisted Crystallizer (MAC), Desalination, Volume 104, Issues 1-2, p. 135-139

Appendix 4

nr. 1 CV leading researcher	
Name and titles	Prof. ir. E. (Eelco) van Beek
Affiliation	Deltares, Rotterdamseweg 185, 2629 HD Delft University of Twente, Drienerlolaan 5, 7522 NB Enschede
Academic/professional career	2007 – present Professor Integrated Water Resources Management, University of Twente (30 %) 2001 – present Water Resources Management Specialist, WL | Delft Hydraulics / since 2008 Deltares 1999 – 2001 Director, Inland Water Systems, WL | Delft Hydraulics 1995 – 1999 Director, River Basin Management, WL | Delft Hydraulics. 1993 – 2004 Professor Integrated Water Resources Management, Delft University of Technology (30 %) 1991 – 1994 Deputy Director, Water Resources and Environment Division, WL | Delft Hydraulics. 1989 – 1990 Head Water Resources Section of the Water Resources and Environment Division, WL | Delft Hydraulics. 1985 – 1989 Team leader Cisadane-Cimanuk Integrated Water Resources Development Project, Indonesia, WL | Delft Hydraulics. 1979 – 1985 Deputy Head Systems Approach Branch, WL | Delft Hydraulics. 1976 – 1979 Project engineer Systems Approach Branch and Density Currents and Transport Phenomena Branch, WL | Delft Hydraulics. 1973 – 1976 United Nations Associate Expert, Iran. 1972 – 1973 Research fellow, Delft University of Technology.
Research expertise	Researcher and project coordinator of interdisciplinary teams on integrated water resources management projects, working in this field since 1973. Experience ranging from concepts and theory (among others through PhD projects), applied research to practical planning and design of river basin management, environmental management and physical planning, with special emphasis on drought risk management and water allocation under drought conditions. Wide international experience (in particular in dry and climate vulnerable countries such as Egypt and Iran) as well as extensive experience on the Netherlands situation. Recent (and on-going) academic research involvement: • Perspectives in Integrated Water Management of River Delta's, Water allocation in river basin management (in cooperation with UU, KNMI, Erasmus and ICES) • IRMA-SPONGE project Living with floods and Integrated Research Project FLOODsite (2000-2009) member Scientific Advisory Board. • Chairman Programme Committee LOICZ (NWO) • Chairman various NWO-ALW Program Committees Geo and Biosphere Recent (and on-going) applied research projects: • Exploration cost-effectiveness measures against drought damage resulting from G+ and W+ climate scenarios (Verkenning kosteneffectiviteit maatregelen tegen droogteschade als gevolg van G+ en W+ - Droogtestudie) • Climate proof fresh water supply Netherlands (Klimaatbestendige Zoetwatervoorziening Nederland - sub-project Deltaprogramme), • Lake Nasser Flood and Drought Control (Nile basin); • Strengthening the Resilience of the Water Sector in Khulna to Climate Change (Bangladesh). • Strengthening IWRM in Mongolia.

nr. 1 CV leading researcher	
10 key publications	1. Haasnoot, M, Middelkoop, H., Beek, E. van and Deursen, W.P.A. van (2009). *A method to develop sustainable water management strategies for an uncertain future,* Sustainable Development, Wiley. 2. Beek, E. van and Li, R. (2009). *Equity principles in integrated water allocation in the Yellow River Basin; Allocation algorithm and implementation*. International Yellow River Forum, November 2009. 3. Beek, E. van and Kwadijk, J.C.J. (2009). *Lake Nasser Flood and Drought Project – Integrating climate change uncertainty and flooding and drought risk*, Reports, Ministry of Water Resources and Irrigation, Cairo, Egypt. 4. Beek, E. van, Haasnoot, M, Meijer; K.M., Delsman, J.R., Snepvangers, J.J.J.C., Baarse, G., Ek, R. van, Prinsen, F.G., Kwadijk, J.C.J., Zetten, J.W. van. (2008). *Verkenning kosteneffectiviteit van grootschalige maatregelen tegen droogteschade als gevolg van de G+ en W+ klimaatscenario's*. Deltares. 5. Beek, E. van.(2009). *Managing Water under Current Climate Variability*, chapter in book 'Climate Change Adaptation in the Water Sector', edited by F. Ludwig, P. Kabat, H. van Schaik and M. van der Valk, Earthscan, UK. 6. Offermans, A, Valkering, P., Haasnoot, M., Beek, E. van; Middelkoop (2008). H. *Advies van de Deltacommissie vraagt breder perspectief* (in Dutch), H_2O / 20 October 2008. 7. Beek, E. van, Hansen, S (2008). *Facing the Future; A call for integrated policies for the Egyptian government to face water scarcity in 2050*, Policy Note and background reports, Ministry of Water Resources and Irrigation, Cairo, Egypt. 8. Alphen, J. van, Beek, E. van, Taal, M. (2006). *Floods, from Defence to Management*, Symposium Proceedings of the 3rd International Symposium on Flood Defence in May 2005, Nijmegen, the Netherlands, Taylor & Francis Group, London, 2006. 9. Beek, E. van, Bozorgy, B., Vekerdy, Z. and Meijer, K.S. (2008). *Limits to agricultural growth in the Sistan Closed Inland Delta, Iran*, Irrigation and Drainage System (2008) 22:131–143, Springer, 2008. 10. Loucks, D.P and Beek, E. van, (2005). *Water Resources Systems Planning and Management – an introduction to methods, models and applications* (600 page text book, December 2005, UNESCO - Paris.

Nr 2 CV leading researcher	
Name and titles	Dr. Ir. A. B. M. (Ad) Jeuken
Affiliation	Deltares, PO Box 177, 2600 MH Delft
Academic/professional career	2007- 2009 - Senior advisor Climate Adaptation, Deltares, Delft 2007 – Head of the Estuaries group - Department of Transport, Public Works and Water Management (Rijkswaterstaat, RIZA) 2003-2006 - Senior advisor water quality and morphology – Rijkswaterstaat RIZA 2000-2003 - Programme manager operational monitoring – Rijkswaterstaat RIZA 1994-2000 – Climate researcher – Royal Dutch Meteorological Institute (KNMI)
Research experience	Advisor and project co-ordinator of interdisciplinary teams on integrated water management, working in this field since 2000. Recent projects: 2007-2009 Climate proofing “Nederland Waterland“ (De klimaatbestendigheid van NL Waterland) – Leading researcher of this large survey and assessment of the climate vulnarability of the Dutch water management and alternative strategies. (Joint project RWS and Deltares). 2007-2008 Assessment framework Spatial planning and climate (afwegingskader ruimte en klimaat) – leading researcher for Deltares in the consortium. “ARK-Routeplanner” project. 2005-2006 – WFD-explorer (KRW-Verkenner) – Leading researcher of research consortium – Innovative project (Leven met water) aimed at the development of a science policy interface for the water framework directive. Ad Jeuken is coordinator and project leader of the Deltares strategic research on climate adaptation water and spatial planning.

10 key publications	1. Jaap Kwadijk, Marjolijn Haasnoot, Marco Hoogvliet, Ad Jeuken, Rob van de Krogt, Jan Mulder, Niels van Oostrom, Harry Schelfhout, Emiel van Velzen, Harold van Waveren and Marcel de Wit. Adapting to Sea level rise in the Netherlands, under review, Wiley Interdisciplinary Reviews: Climate Change, 2009 2. Ad Jeuken, W. Bruggeman (editors) – Watermanagement in a changing climate (Waterbeheer in een veranderend klimaat : Feiten en fictie van tachtig beweringen in de media) Ministerie van Verkeer en Waterstaat (VenW), Deltares, 2008. 3. Kwadijk, Jaap; Marjolijn Haasnoot; Marco Hoogvliet; Ad Jeuken; Rob van der Krogt; Niels van Oostrom; Harry Schelfhout; Emiel van Velzen; Marcel de Wit & Harold van Waveren, Klimaatbestendigheid van Nederland als waterland, H20 23-2008, pp. 10-12, 2008 4. Jeuken, A., E. Opdam, A. Leusink, R. van der Krogt, F. Claessen, H. van der Most, E. Metselaar en B. McCarthy (2008). Towards a climate proof Netherlands – framework for decision making (Naar een klimaatbestendig Nederland. Kaders voor afweging), Definitiestudie fase 1. Leven met Water. 20 maart 2008. 5. J.Kwadijk, A.Jeuken and H. van Waveren -Klimaatbestendigheid van Nederland Waterland: Knikpunten in beheer en beleid voor het hoofdwatersysteem. Climate proofing Nederland Waterland: Tipping points in the management and policy for the main water system Compiled by; Interim project report T2447 Deltares, 2008. .

	6. Ad Jeuken and Harold van Waveren - Three perspectives for a climate proof Netherlands. Adaptation measures for the Dutch water management (Drie perspectieven voor een klimaatbestendig Nederland. Adaptatiemaatregelen voor het Nederlandse waterbeheer). Interim report on behalf of the Delta Commission. Deltares/RWS september 2008. 7. Peñailillo Burgos, Reinaldo; Joost Icke & Ad Jeuken, Effects of the meteorological conditions and cooling water discharges on the water temperature of Rhine River, 12th International Conference on Integrated Diffuse Pollution Management (IWA DIPCON 2008), 2008. 8. Ans M. Mouton, Herman Van Der Most, Ad Jeuken, Peter L. M. Goethals, Niels De Pauw - Evaluation of river basin restoration options by the application of the Water Framework Directive Explorer in the Zwalm River basin (Flanders, Belgium), River research and applications, 2008

nr. 3 CV leading researcher	
Name and titles	Dr. Ir. G.H.P. (Gualbert) Oude Essink
Affiliation	Deltares, Unit Subsurface and Groundwater Systems, Princetonlaan 6, 3584 CB Utrecht
Academic/professional career	2002-date Deltares, Unit Subsurface and Groundwater Systems, formerly TNO Built Environment and Geosciences. Geological Survey of The Netherlands 2002-2004 Free University of Amsterdam, Faculty of Earth and Life Sciences, Hydrology and Geo-Environmental Sciences (part-time): EC-project CRYSTECHSALIN 2000-date Lecturer IHE Delft (International Institute for Infrastructural Hydraulic and Environmental Engineering) on density dependent groundwater flow 1997-2002 Assistant Professor University of Utrecht, Faculty of Earth Sciences, Theoretical Geophysics 1989-1996 Ph.D. Delft University of Technology, Civil Engineering, Hydrology and Ecology: 'Impact of sea level rise on groundwater flow regimes. A sensitivity analysis for the Netherlands' 1984-1989 M.Sc. Delft University of Technology, Civil Engineering, Hydrology Gualbert is a member of the advisory board of the Polish Geological Survey and is an Associate Editor of Hydrogeology Journal. He is also a member of the scientific committee of the Salt Water Intrusion Meetings and the Int. Symp. on Technology of Seawater Intrusion into Coastal aquifers.
Research expertise	Gualbert Oude Essink is senior hydrogeologist. He has experience in the field of coupled density dependent groundwater flow and salt transport (salt water intrusion) in regional and local water systems. He involved in research on the effects of human activities and climate change to groundwater and surface water in the coastal zone. He is involved in numerous studies on the effect of climate change and sea level rise, e.g., for Provinces (Zeeland, Zuid-Holland, Friesland, Groningen), Waterboards (Rijnland, Delfland, Wetterskip Fryslan, Hollands Noorderkwartier) and Netherlands' government (Rijkswaterstaat, PBL and VROM). Gualbert gives international courses and keynote lectures on groundwater related themes. Some past, recent and on-going projects: 2009: Development of the density dependent groundwater module of the Netherlands Hydrological Modelling Instrument (NHI), funded Rijkswaterstaat 2009: Consolidate Learning from the Salinity Ingress Prevention Measures undertaken in the Coastal Area of Gujarat, India 2010-2011: Interreg IVB ScaldWIN: on the future salinisation of the coastal transboundary area Oost-Vlaanderen (Belgium) and Zeeuws-Vlaanderen (Netherlands) 2009-2011: Interreg IV Climate Proof Areas: the aim of the project is to accelerate the climate change adaptation process in the North Sea Region by means of the joint development and testing of innovative adaptation measures in pilot locations 2008-2011: Interreg IV CliWat: on determining the effects of climate change on groundwater systems and through this on surface water and water supply. 2005-2009: Salinisation and freshening of phreatic groundwater in the Province of Zeeland 2001-2004: EU-project Crystechsalin (EESD-ENV-2000-0159): Crystallisation Technologies for Prevention of Salt Water Intrusion
10 key publications	1. Goes, B.J.M., Oude Essink, G.H.P., Vernes, R.W. and Sergi, F. 2009. Estimating the depth of fresh and brackish groundwater in a predominantly saline region using geophysical and hydrological methods, Zeeland, the Netherlands, Near Surface

nr. 3 CV leading researcher	
	Geophysics 401-412. 2. Louw, P.G.B., de, Oude Essink, G.H.P., Stuyfzand, P.J., Zee, van der, S.E.A.T.M., Boils: the dominant mechanism of surface water salinization in reclaimed lake areas in The Netherlands, J. Hydrol. (submitted 2009). 3. Oude Essink, G.H.P., Baaren, E., van & Vliet, M. van (2008). Exploratory investigation on climate change and salinisation of groundwater in Zuid-Holland (in Dutch: Verkennende studie klimaatverandering en verzilting grondwater in Zuid-Holland), Deltares-report 2008-U-R0322/A, 60 p. 4. Giambastiani, B.M.S., Antonellini, M., Oude Essink, G.H.P. & Stuurman, R.J. (2007). Saltwater intrusion and water management in the unconfined coastal aquifer of Ravenna (Italy): a numerical model, J. Hydrol., Vol. 340, no. 1-2, pp. 91-104. 5. Oude Essink, G.H.P. (2007).Effect sea level rise on groundwater in the coastal zone (in Dutch), H2O 19, 60-64. 6. Oude Essink, G.H.P. (2001). Salt Water Intrusion in a Three-dimensional Groundwater System in The Netherlands: A Numerical Study, Transport in Porous Media, 43 (1): 137-158. 7. Oude Essink, G.H.P. (2001). Improving Fresh Groundwater Supply - Problems and Solutions, UNESCO International workshop on cities and coasts, Challenges of growing urbanization of the world's coastal areas, Ocean & Coastal Management, 44 (5/6), 429-449. 8. Oude Essink, G.H.P. (1997). Effects of sea level rise. In: Seawater intrusion in coastal aquifers: guidelines for study, monitoring and control. Water reports 11, FAO, Rome. 43-56. 9. Oude Essink, G.H.P. (1996). Impact of sea level rise on groundwater flow regimes. A sensitivity analysis for the Netherlands. Ph.D. thesis Delft University of Technology. Delft Studies in Integrated Water Management: no. 7 (ISBN 90-407-1330- 8). 428 p. 10. Oude Essink, G.H.P., R.H. Boekelman, *et al.*, (1993), Physical impacts of sea level change, State of the Art Report UNESCO Workshop SEACHANGE'93. Sea Level Changes and their Consequences for Hydrology and Water Management, April, 1993, Noordwijkerhout, the Netherlands, UNESCO, IHP-IV Project H-2-2. Noordwijkerhout, the Netherlands: 1-137

nr 4 CV leading researcher	
Name and titles	Prof. Dr. Ir. S.E.A.T.M. (Sjoerd) van der Zee
Affiliation	Wageningen University, Environmental Sciences Group, Soil Physics, Ecohydrology, and Groundwater Management
Academic career	1984-1987 PhD Student 1987-1988 scientist (temporal position) 1988-1992 assistant professor (UD) 1992-1998 associate professor (UHD; personal appointment; persoonlijk UHD) 1998-2005 full professor (personal appointment; persoonlijk hoogleraar) 2005- full professor and chair, Soil Physics, Ecohydrology, and Groundwater Management President Dutch Soil Science Society (2000-2004), chair Boussinesq Center for Hydrology (2005-2008), Director of Science SENSE graduate school 2000-2003; Director Wageningen Institute of Environment and Climate Research (WIMEK; 2003-2005); Chair WIMEK General Board; several other directorships Chair Scientific Advisory Board and member Supervisory Board, UFZ, Helmholtz, DE. Numerous committees; about 200 publications; numerous times key note speaker at conferences; reviews for many journals and national science foundations.
Research expertise	Transport of reactive chemicals in soil and groundwater Upscaling reactive transport in spatiotemporally variable media with stochastic methods Soil and groundwater salinity, sodicity and waste water re-use Ecohydrology of semi-arid regions Multiphase water-air-oil flow processes and modelling System's analysis approach to soil and groundwater pollution problems Biological availability of inorganic contaminants for plants and soil biota
10 key publications	1. Vervoort, R.W., S.E.A.T.M. van der Zee (2008). Simulating the effect of capillary flux on the soil water balance in a stochastic ecohydrological framework, Water Resour. Res., Vol. 44, W08425, doi:10.1029/2008WR006889. 2. Vervoort, R.W., S.E.A.T.M. van der Zee, Stochastic soil water dynamics of phreatophyte vegetation with dimorphic root systems, Water Resour. Res. (in press) 3. Van der Zee, S.E.A.T.M., S.H.H. Shah, C.G.R. van Uffelen, P.A.C. Raats, and N. dal Ferro, Soil sodicity as a result of periodical drought, Agricultural Water Management (in press). 4. Beltman, W.H.J., J.J.T.I. Boesten, S.E.A.T.M. van der Zee (2008). Spatial moment analysis of transport of nonlinearly adsorbing pesticides using analytical approximations, Water Resour. Res., W05417, doi:10.1029/2007WR006436 5. Van Asten, P.J.A., L. Barbiero, M.C.S. Wopereis, J.L. Maeght, and S.E.A.T.M. van der Zee (2003). Actual and potential salt-related soil degradation in an irrigated rice scheme in the Sahelian zone of Mauretania, Agric. Water Management 60, 13-32. 6. Khoshgoftar, A.H., H. Shariatmadari, N. Karimian, M. Kalbasi, S. van der Zee and D.R. Parker (2004). Salinity and zinc application effects on phytoavailability of cadmium and zinc. Soil Science Society of America Journal, 68(6): 1885-1889 7. P.G.B. de Louw, G.H.P. Oude Essink, P.J. Stuyfzand, S.E.A.T.M. van der Zee. Boils: the dominant mechanism of surface water salinization in reclaimed lake areas in The Netherlands, J. Hydrology, submitted (2009) 8. Van Dijke, M.I.J., and S.E.A.T.M. van der Zee (1998). Analysis of oil lens removal by extraction through a seepage face, *Comput. Geosci.*, 2, 47-72 9. Eeman, S., A. Leijnse, and S.E.AT.M. van der Zee, The transition zone between a fresh water lens and underlying saline water, Advances in Water Resour.,

nr 4 CV leading researcher	
	submitted (2009). 10. D.G. Cirkel, J-P M. Witte, S.E.A.T.M. van der Zee, Estimating seepage intensities from groundwater level time series on a spatial scale that fits plant communities, J. Hydrol., submitted (2009).

nr 5 CV leading researcher	
Name and titles	Prof. dr. P. J. (Pieter) Stuyfzand
Affiliation	KWR Watercycle Research Institute (Nieuwegein) 3d/week VU University Amsterdam (VU) 2d/week
Academic career	2004 Part-time, full professor and chair 'Chemical Hydrogeology' 1993 Ph.D. VU University Amsterdam on 'Hydrochemistry and hydrology of the coastal dune area of the Western Netherlands 1978 M.Sc. in hydrogeology, VU University Amsterdam (cum laude) 1975 B.Sc. in physical geography, VU University Amsterdam
Research expertise	Pieter Stuyfzand is full professor with a chair in chemical hydrogeology, and head of the Hydrogeology group at VU University Amsterdam. He has 30 years of professional experience in the fields of hydrogeochemistry and hydrogeology, with a focus on the following: Managed Aquifer Recharge (MAR, including artificial recharge, river bank filtration, rain water harvesting etc.); coastal aquifer systems (hydrology and hydrogeochemistry), hydrological and hydrochemical system analysis; mapping (ground)water quality using water typologies and water quality indices; expert models for reactive solute transport; design and evaluation of monitoring systems for groundwater and soil quality; chemical dating and multi-tracing of groundwater; interaction between atmosphere, vegetation, geochemistry and groundwater quality; behaviour of pollutants in groundwater flow systems; geochemical, sedimentological and geological characterisation of aquifers and aquitards; and clogging and rehabilitation of infiltration and pumping wells. He is also a member of the scientific advisory board of recurrent symposia on salt water intrusion (SWIM) and Managed Aquifer Recharge (ISMAR), and a member of the OBN expert team 'Dunes and Coast'.
10 key publications	1. Stuyfzand, P.J. & K.J. Raat 2010. Benefits and hurdles of using brackish groundwater as a drinking water source in the Netherlands. Accepted by Hydrogeol. J. DOI: 10.1007/s10040-009-0527-y 2. Stuyfzand, P.J. & R.J. Stuurman 2008. Origin, distribution and chemical mass balances for brackish and saline groundwaters in the Netherlands. Proc. In: G. Barrocu (ed) Proc. 1st SWIM-swica Joint Saltwater Intrusion Conference, Cagliari-Baia de Chia, Sept24-29 2006, 151-164. 3. Stuyfzand, P.J. 2008. Base exchange indices as indicators of salinization or freshening of (coastal) aquifers. In: Program and Proceedings 20th Salt Water Intrusion Meeting, June 23-27 2008, Naples (Fl) USA, Univ Florida, IFAS Research, 262-265. 4. Stuyfzand, P.J. 2006. Mapping groundwater bodies with artificial or induced recharge, by determination of their origin and chemical facies. Proc. 5th Intern. Symp. on Management of Aquifer Recharge, ISMAR-5, Berlin 11-16 June 2005, UNESCO IHP-VI, Series on Groundwater No. 13, 839-850. 5. Prommer, H. & P.J. Stuyfzand 2005. Identification of temperature-dependent water quality changes during a deep well injection experiment in a pyritic aquifer. Environ. Sci. & Technol. 39, 2200-2209. 6. Stuyfzand, P.J. & J. Kappelhof. 2005. Floating, high-capacity desalting islands on renewable multi-energy supply. Desalination 177 (2005), 259-266. 7. Saaltink, M.W., C. Ayora, P.J. Stuyfzand & H. Timmer 2003. Analysis of a deep well recharge experiment by calibrating a reactive transport model with field data. J. Contaminant Hydrol 65, 1-18. 8. Stuyfzand, P.J. 1999. Patterns in groundwater chemistry reflecting groundwater

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	flow. Hydrogeol. J. 7, Theme issue 'Groundwater as a geologic agent', J. Tóth (ed), Hydrogeology J. (7), 15-27. 9. STUYFZAND, P.J. 1995. The impact of land reclamation on groundwater quality and future drinking water supply in The Netherlands. Water Sci & Technol. 31 (1995), 47-57. 10. Stuyfzand, P.J. 1989. Hydrology and water quality aspects of Rhine bank ground water in The Netherlands. J. Hydrol. 106, 341-363.

Nr 6 CV leading researcher	
Name and titles	Prof. dr. ir. J-P. M. (Flip) Witte
Affiliation	KWR Watercycle Research Institute, P.O. Box 1072 3430 BB Nieuwegein, The Netherlands.
Academic/professional career	2007-present: Extra-ordinary professor at Vrije Universiteit, Systems Ecology Group 2005-present: Principal Researcher at KWR 1991-2005: Assistant and Associate professor at Wageningen University, Soil physics, Ecohydrology and Groundwater management Group. 1987-1991: Institute of Integrated water Management and Waste Water Treatment. 1983-1987: Hydrological and ecological research at a number of institutes
Research experience	Witte specializes in relationships between groundwater and terrestrial vegetation, with emphasizes on the ecological effects of both water management and climate change. He obtained his doctoral in 1998 with his thesis *National Water Management and the Value of Nature*. In 2004, Witte was awarded with the prestigious four-yearly research price of the Wageningen University Fund for his article *Scale dependency and fractal dimension of rarity* (Ecography 26: 60-68). During his professional career, Witte published articles and scientific reports about the ecological consequences of water management and climate change, effects of locale measures to re-wet conservation areas, the relationship between vegetation and soil moisture and soil chemistry, scale and heterogeneity, methods to classify vegetation, indicator values of plant species for habitat factors, rarity, methods to quantify the conservation value of nature and predictive eco-hydrological models (DEMNAT, PROBE).

10 key publications	1. Bartholomeus, R.P., J.P.M. Witte, P.M. van Bodegom, J.C. van Dam & R. Aerts, 2008. Critical soil conditions for oxygen stress to plant roots: Substituting the Feddes-function by a process-based model. *Journal of Hydrology* 360: 147-165. 2. Bartholomeus, R.P., J.P.M. Witte, P.M. van Bodegom & R. Aerts, 2008. The need of data harmonization to derive robust empirical relationships between soil conditions and vegetation. *Journal of Vegetation Science* 19: 799-808. 3. Kruijt, B., J.P.M. Witte, C. Jacobs & T. Kroon, 2008. Effects of rising atmospheric CO_2 on evapotranspiration and soil moisture: a practical approach for the Netherlands. *Journal of Hydrology* 349: 257-267. 4. Ordoñez, J.C., P.M. van Bodegom, J.P.M. Witte, I.J. Wright, P.B. Reich, R. Aerts, 2009. A global study of relationships between leaf traits, climate and soil measures of nutrient fertility. *Global ecology and Biogeography* 18: 137-149. 5. Ordoñez, J.C., P.M. van Bodegom, J.P.M. Witte, R.P. Bartholomeus, J.R. van Hal & R. Aerts, accepted. Plant strategies in relation to resource supply in mesic to wet environments: does theory mirror nature? *American Naturalist*. 6. Witte, J.P.M., R.P. Bartholomeus, D.G. Cirkel & P.W.T.J Kamps, 2008. *Ecohydrologische gevolgen van klimaatverandering voor de kustduinen van Nederland*. (in Dutch: ecohydrological effects of climate change on Dutch coastal dunes). Scientific report, Nieuwegein. 7. Witte, J.P.M., F. He & C.L.G. Groen, 2008. Grid origin affects scaling of species across spatial scales. *Global Ecology and Biogeography* 17: 448-456. 8. Witte, J.P.M., J. Runhaar & R. van Ek, 2008. *Ecohydrological modelling for managing scarce water resources in a groundwater-dominated temperate system*. In: Harper, D., M. Zalewski, E. Jorgensen & N. Pacini (eds.), Ecohydrology: Processes, Models and Case Studies, p. 88-111. CABI

	Publishing, Oxfordshire, UK. 9. Witte, J.P.M., J. Runhaar & R. Van Ek, 2009. *Ecohydrologische effecten van klimaatverandering op de vegetatie van Nederland* (in Dutch: ecohydrological effects of climate change on the vegetation of the Netherlands). Scientific report, Nieuwegein. 10. Witte, J. P. M., R. B. Wojcik, P. Torfs, M. W. H. de Haan and S. Hennekens, 2007. Bayesian classification of vegetation types with Gaussian mixture density fitting to indicator values. *Journal of Vegetation Science*, 18(4): 605-612

nr 7 CV leading researcher	
Name and titles	Dr. J.J.G. (Gertjan) Zwolsman
Affiliation	KWR Watercycle Research Institute
Academic/professional career	2008-now Head of the team Integrated water management, KWR 2004-2007 Principal researcher Water resources management, KWR 1999 PhD Geochemistry, Utrecht University 1994-2004 Head of the team Water quality, National Institute for Inland Water Management and Waste Water Treatment (RIZA) 1991-1994 Researcher Water quality modelling, WL | DELFT HYDRAULICS 1987-1990 Junior scientist Water quality research, National Institute for Marine and Coastal Management (RIKZ) 1987 MSc Inorganic Chemistry, Utrecht University *(cum laude)*
Research expertise	Gertjan Zwolsman is head of the team Integrated water management which forms part of the Water systems department of KWR. He is a specialist in water quality issues and has a strong background in integrated water management. Current fields of interest are impacts of climate change on water management (with particular focus on water quality) and consequences of the European Water Framework Directive on water quality and drinking water production. He is also the co-ordinator of the water resources research programme of KWR and secretary to the IWA Specialist Group on Climate Change. Gertjan studied inorganic chemistry and geochemistry and has 20-years experience in water quality research, water quality modeling, and integrated water management. Keywords in specialisation are: Water quality research, integrated water management, climate change and water (impact analysis, adaptation), Water Framework Directive.
10 Key publications	1. Zwolsman, J.J.G., Johannesen, A., et al. (2009). Climate Change and the Water Industry. Asian Water, September 2009: 10-15. 2. Wilbers, G., Zwolsman, G., Klaver, G. & Hendriks, J. (2009). Effects of a drought period on physico-chemical surface water quality in a regional catchment area. Journal of Environmental Monitoring, 11: 1298-1302. 3. M.T.H. Van Vliet & J.J.G. Zwolsman (2008). Impact of summer droughts on the water quality of the Meuse River. Journal of Hydrology 353: 1-17. 4. A. Doomen, E. Wijma, J.J.G. Zwolsman & H. Middelkoop (2008). Predicting suspended sediment concentrations in the Meuse River using a supply-based rating curve. Hydrological Processes 22: 1846-1856. 5. J.J.G. Zwolsman & A. van Bokhoven (2007). Impact of summer droughts on the water quality of the Rhine River - a preview of climate change? Water Science & Technology 56 (4): 45–55. 6. A.F.M. Meuleman, G. Cirkel & J.J.G. Zwolsman (2007). When Climate change is a fact! Adaptive strategies for drinking water production in a changing natural environment. Water Science & Technology 56 (4): 137-144. 7. H.A.J. Senhorst & J.J.G. Zwolsman (2005). Climate change and effects on water quality: a first impression. Water Science & Technology 51: 53-60. 8. Moermond, C.T.A., Zwolsman, J.J.G. & Koelmans, A.A. (2005). Black carbon and ecological factors affect in situ BSAFs for hydrophobic organic compounds in flood plain lakes. Environmental Science and Technology 39: 3101-3109. 9. Moermond, C.T.A., F.C.J.M. Roozen, J.J.G. Zwolsman & A.A. Koelmans (2004). Uptake of sediment-bound bioavailable polychlorobiphenyls by benthivorous carp (*Cyprinus carpio*). Environmental Science and Technology 38: 4503-4509. 10. Kramer, K.J.M., R.G. Jak, B. van Hattum, R.N. Hooftman & J.J.G. Zwolsman

nr 7 CV leading researcher	
	(2004). Copper toxicity in relation to surface water dissolved organic matter: biological effects to *Daphnia magna*. Environmental Toxicology and Chemistry 23: 2971-2980.

nr 8 CV leading researcher	
Name and titles	Dr. Ir. Marcel A.A. Paalman
Affiliation	KWR Watercycle Research Institute
Academic/professional career	2009 KWR Watercycle Research Institute (sept.2009). Senior advisor 2006- 2009 Secretary of the Delta Council/Steering committee South-West Delta 1998-2006 Senior policy advisor water, Province of South Holland 1996 Thesis: "Processes affecting the distribution and speciation of heavy metals in the Rhine/Meuse estuary". University of Utrecht. 1993-1998 Policy advisor water, Municipality of Amsterdam 1989-1993 Researcher Geochemistry, Department of Earth Sciences, University of Utrecht Teacher in thermodynamics and chemical kinetics 1989 M. Sc. in Soil chemistry , University of Wageningen
Research expertise	The (research) expertise of Marcel Paalman is especially focussed on aspects of water quality. The last decade he worked at as senior policy advisor and secretary of the Delta Council/Steering committee SW Delta. The Delta Council/Steering committee South West Delta is an high administration group with participation of State (Ministry of transport, Public Works and Water management, Ministry of Agriculture, Nature and Food quality) , provinces of South Holland, Zeeland and North Brabant and the inset Waterboards. Their task is to make this delta region climate proof, restore estuarine dynamics and to improve the economic situation. An important issue in this region is that restoration of the estuarine dynamics (ecology) results in a transition from fresh water to more saline water, which causes problems for the fresh water dependent sectors (eg. drinking water, agriculture and industry). In the western part of the Netherlands the intrusion of brackish water (via groundwater or surface water) poses a major water quality problem. As senior advisor and/or secretary he advises the involved public organisations on policy and strategic aspects. Before his work in the public sector he was a researcher at the University of Utrecht working on the geochemical behaviour of trace metals in the Rhine/Meuse estuary.
Publications	1. Anonymus 2009, Provinciaal Waterplan 2010-2015, Provincie Zuid-Holland 2. Anonymus 2009, Zoet water Zuidwestelijke Delta, Stuurgroep Zuidwestelijke Delta 3. Anonymus 2003-2009. Various reports on water quality subjects, eg. swimming water policy and sediment and sludge policy, Province of South Holland 4. Anonymus 2003, Nota Uitvoeringsbeleid Baggerspecie (III).Provincie Zuid-Holland 5. M.A..A. Paalman 1996. Processes affecting the distribution and speciation of heavy metals in the Rhine/Meuse estuary (thesis). Geologica Ultraiectina no.148, University of Utrecht. 6. M.A..A. Paalman, C.H. van der Weijden, J.P.G. Loch 1994 Sorption of cadmium on suspended matter under estuarine conditions: competition and complexation with major-sea water ions. Water, Air and Soil Pollution 73: 49-60.

nr 9 CV senior scientific researcher	
Name and titles	Dr. Ir. E.R. (Emile) Cornelissen
Affiliation	KWR Watercycle Research Institute
Academic/professional career	2005-now Senior Scientific Researcher, Water Treatment team, KWR 2003-2005 Scientific Researcher, Water Treatment team, KWR 2000-2002 Start-up & Process Engineer, Seghers Better Technology for Water (Belgium) 1997-2000 Sales & Process Engineer, Seghers Better Technology for Water (Belgium) 1992-1997 PhD Chemical Engineering, Membrane Technology, Twente University 1992 MSc Chemical Engineering, Twente University
Research expertise	Emile Cornelissen is Senior Scientific Researcher in the Water Treatment team which is part of the Water Technology department of KWR. He is a specialist in membrane technology and has 18 years of experience in this field. More specifically he is the leading researcher in several (membrane) projects concerning membrane fouling (biofouling, organic fouling), membrane retention of organic micro-pollutants, ceramic membrane filtration and innovative membrane processes (e.g. application of air/water cleaning for fouling control, development of osmotic driven membrane bioreactors). He is researcher is several international research projects including Awwarf NF modelling, Awwarf biofouling, Medina sea water desalination and Techneau ceramic membrane filtration. Emile studied chemical engineering and has 18-years research experience in membrane technology, including membrane fouling and cleaning, membrane process design, membrane modeling and developing innovative membrane applications. Keywords in specialisation are: Membrane Technology, Desalination, Forward Osmosis, Ion Exchange and Water Treatment.
10 Key publications	1. Cornelissen, E. R., E. F. Beerendonk, et al. (2009). "Fluidized ion exchange (FIX) to control NOM fouling in ultrafiltration." Desalination **236**(1-3): 334-341. 2. Verliefde, A. R. D., E. R. Cornelissen, et al. (2009). "Influence of solute-membrane affinity on rejection of uncharged organic solutes by nanofiltration membranes." Environmental Science and Technology **43**(7): 2400-2406. 3. Hijnen, W.A.M., D. Biraud, E.R. Cornelissen and D. van der Kooij (2009). “Threshold concentration of easily assimilable organic carbon in feedwater for biofouling of spiral-wound membranes.” Environmental Science and Technology **43**: 2490-2495. 4. Cornelissen, E. R., D. Harmsen, et al. (2008). "Membrane fouling and process performance of forward osmosis membranes on activated sludge." Journal of Membrane Science **319**(1-2): 158-168. 5. Cornelissen, E. R., N. Moreau, et al. (2008). "Selection of anionic exchange resins for removal of natural organic matter (NOM) fractions." Water Research **42**(1-2): 413-423. 6. Cornelissen, E. R., J. S. Vrouwenvelder, et al. (2007). "Periodic air/water cleaning for control of biofouling in spiral wound membrane elements." Journal of Membrane Science **287**(1): 94-101. 7. Cornelissen, E. R., W. G. Siegers, et al. (2006). Influence of calcium-NOM complexes on fouling of nanofiltration membranes in drinking water production. Water Science and Technology: Water Supply. **6:** 171-178. 8. Cornelissen, E.R., J. Verdouw, et al. (2005). “A nanofiltration retention model for trace contaminants in drinking water sources.” Desalination **178**: 179-192. 9. Cornelissen, E. R., W. Janse, et al. (2002). "Wastewater treatment with the internal MEMBIOR." Desalination **146**(1-3): 463-466. 10. Cornelissen, E. R., T. Van Den Boomgaard, et al. (1998). "Physicochemical aspects

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	of polymer selection for ultrafiltration and microfiltration membranes." Colloids and Surfaces A: Physicochemical and Engineering Aspects **138**(2-3): 283-289.

nr. 10 CV leading researcher	
Name and titles	Dr. V.E.A. (Vincent) Post
Affiliation	VU University, Faculty of Earth and Life Sciences, Department of Hydrology and Geo-Environmental Sciences, De Boelelaan 1085, 1081 HV, Amsterdam, The Netherlands
Academic career	2004-date VU University, Faculty of Earth and Life Sciences, Department of Hydrology and Geo-Environmental Sciences 2003-2004 TNO Built Environment and Geosciences. Geological Survey of The Netherlands 1999-2003 VU University, PhD student
Research expertise	Vincent Post completed a PhD on fresh-salt groundwater interactions in 2003. Currently he works as an assistant professor in hydrogeology at the VU University in Amsterdam. Vincent Post is an expert in the modelling of solute transport and chemical reactions in groundwater. He further specializes in the hydrogeology of coastal aquifers and has worked on several projects on coupled variable density groundwater flow and solute transport, including laboratory, field and modelling studies. His research focuses on the dynamics of fresh and saline groundwater in coastal areas, the offshore extension of fresh groundwater flow systems, the rates of salinisation by free convection and the development and application of coupled groundwater models. He is the co-developer of the widely used computer code PHT3D and a collaborator on national and international projects in which this code is used. He teaches courses on geology, groundwater and geochemical modelling. He is an associate editor for Hydrogeology Journal and a member of the scientific committee of the Salt Water Intrusion Meeting.
10 key publications	1. Post, V.E.A. & C.T. Simmons (2009). Free convective controls on sequestration of salts into low-permeability strata: insights from sand tank laboratory experiments and numerical modelling. Hydrogeology Journal DOI 10.1007/s10040-009-0521-4. 2. Post, V.E.A. & B.M. van Breukelen Changes in groundwater and baseflow composition due to climate change: Effects of shifts in the seasonal rainfall distribution. Water Resources Research (submitted 2009) 3. Post, V.E.A. & H. Prommer (2007). Multicomponent reactive transport simulation of the Elder problem: effects of chemical reactions on salt plume development. Water Resources Research 43(10), DOI W1040410.1029/2006WR005630 4. Post, V.E.A., H. Kooi, C.T. Simmons (2007). Using Hydraulic Head Measurements in Variable-Density Ground Water Flow Analyses. Ground Water: DOI 10.1111/j.1745-6584.2007.00339.x 5. Post, V.E.A. (2005). Fresh and saline groundwater interaction in coastal aquifers: is our technology ready for the problems ahead? Hydrogeology Journal 13(1): DOI 10.1007/s10040-004-0417-2 6. Post, V.E.A., H. van der Plicht & H.A.J. Meijer (2003). The origin of brackish and saline groundwater in the coastal area of the Netherlands. Netherlands Journal of Geosciences / Geologie en Mijnbouw 82: 131-145. 7. Post, V.E.A. (2004). Groundwater salinization processes in the coastal area of the Netherlands due to transgressions during the Holocene. PhD. thesis, Vrije Universiteit Amsterdam, 138 pp. 8. Bonte, M., J. Geris, V.E.A. Post, V. Bense, H. Van Dijk (2007). Mapping Groundwater-Surface Water Interactions And Associated Geological Faults Using Temperature Profiling. In: Proceedings of the XXXV IAH congress, Groundwater and ecosystems, Lisbon 2007. Edited by: Ribeiro, L., A. Chambel, M.T. Condessa de Melo

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	9. Groen, M., Kok, A., Van der Made, K. J. & Post, V. E. A. (2008). The Use of Mapping the Salinity Distribution Using Geophysics on the Island of Terschelling for Groundwater Model Calibration. Proceedings of the 20th Salt Water Intrusion Meeting, Naples, Florida, 23-27 June 2008 p. 124-127 10. Oude Essink, G.H.P., V.E.A. Post, M.J.M Kuijper & B. Minnema (2005). Land Subsidence and sea level rise threaten the coastal aquifer of Zuid-Holland, the Netherlands. In: Groundwater and saline intrusion - Selected papers from the 18th Salt Water Intrusion Meeting. Edited by: Araguas, L., E. Custodio & M. Manzano. IGME, Madrid: 617-624.

nr. 11 CV leading researcher	
Name and titles	Prof.Dr. J. (Jelte) Rozema
Affiliation	Chair Climate-Biosphere Interactions, Department of Systems Ecology, Institute of Ecological Science VUA
Academic career	1968-1970 BSc: Biology with Earth Sciences, Vrije Universiteit, Amsterdam, 1971-1974 MSc: Plant Ecology, Biomathematics, Vrije Universiteit, Amsterdam, Prof.Dr. L.W. Kuilman, Prof. Dr. W. H. O. Ernst, Population genetics, Utrecht University, Prof. Dr. W. Scharloo, 1974-1978 PhD research: Ecophysiology of halophytes. Promotores Prof. Dr. W.H.O. Ernst, Prof. Dr. R. Brouwer, Prof dr Yoav Waisel (Tel Aviv), 1979 Sabbatical with Prof Hal Mooney Stanford University, San Francisco; Prof Martyn Caldwell, USU, Logan, Utah 1978-1986 Lecturer Department of Ecology, VUA 1986-2003 Senior Lecturer (Associate Professor, Universitair Hoofddocent) in Ecophysiology of Plants, Department of Ecology and Ecotoxicology, VUA 2003-Present Chair Climate-Biosphere Interactions, Department of Systems Ecology, Institute of Ecological Science VUA
Research expertise	<u>Research themes</u> Ecophysiology and systems ecology of halophytes and coastal ecosystems, Saline agriculture and salt tolerance of crops, Plant-Ecosystem-Climate interactions Plant-Climate indicator studies, Ecosystem responses to simulated warming, Ecosystem changes along latitudinal gradients, Development and validation of plant based climate-temperature proxies, Development and validation of plant based solar UV proxies. 2009 Chairman EC Cost Halophytes workgroup Economic and agricultural use of halophytes 2009- Member management team EC COST programme Putting Halophytes to Work - From Genes to Ecosystems, 1993- 2000 Chairman Netherlands Global Change and Terrestrial Ecosystems (GCTE) Committee, 1993 -2007 Member Dutch IGBP-WCRP-International Geosphere-Biosphere Programme of the Council of the Netherlands Royal Academy of Sciences (KNAW) 1987 – 1993 Vice-chairman NWO-council CO_2-research
10 key publications	1. J.Rozema, T. J. Flowers. (2008). Crops for a salinized World. Science 322, 1478-1479. 2. J. Rozema, (1996). in: Halophytes and biosaline agriculture. R. Choukr-Allah, C.V. Malcolm, A. Hamdy, Eds, (Marcel Dekker, New York, pp. 17-30. 3. B.H. Niazi, J.Rozema, R.A. Broekman, M. Salim (2000). Dynamics of growth and water relations of fodderbeet and seabeet in response to salinity. J. Agr. Crop Sci 184,101-109. 4. J. Rozema, S .H. Zaheer, B. H.Niazi, H. Linders, R. Broekman. (1993). Salt tolerance of Beta vulgaris: a comparison of the growth of seabeet and fodderbeet in response to salinity. In: Towards the rational use of high salinity tolerant plants 2: agriculture and forestry under marginal soil water conditions. H. Lieth & A.A. Al Masoom eds. Kluwer Academic Publishers, Dordrecht, pp. 193-197. 5. J. Rozema, B. van Geel, L.O. Bjorn, J. Lean , S. Madronich. (2002). Toward solving the UV puzzle. Science 296,162-1622. 6. Niazi, B.H. (2007). The response of fodderbeet to salinity. Introduction of a non-

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	conventional fodder crop (fodderbeet) to salt-affected fields of Pakistan. pp.199 .ISBN 978-969-409-188-4. PhD Thesis Vrije Universiteit. 7. Rozema, J., Broekman, R.A., Weijers, S., Buizer, D.A.G., Blokker, P., Werleman, C., El Yaqine, H., Hoogedoorn, H., Mayoral Fuertes, M.A., Cooper, E. (2008). Annual growth of Cassiope tetragona as a proxy for arctic climate change:developing transfer functions from growth-temperature correlations and simulated warming in the high Arctic. Global Change Biology. 8. Rozema, J., Boelen, P., Blokker, P. (2005). Depletion of stratospheric ozone over the antarctic and arctic: Responses of plants of polar terrestrial ecosystems to enhanced UV-B, an overview. Environmental Pollution. 137: 428-442. 9. Rozema, J., Aerts, R., Cornelissen, H. eds (2006). Plants and climate change. Springer. 10. J. Rozema, H. Lambers, S.C. van de Geijn & M.L. Cambridge (1993). CO2 and Biosphere. Kluwer Academic Publishers. Dordrecht pp. 484.

nr. 12 CV leading researcher	
Name and titles	Prof. dr. A. (Anne) van der Veen
Affiliation	University Twente – Department of Water Engineering and Management
Academic career	1999- : Professor in Spatial Economics, Faculty of Engineering Technology, Civil Engineering, Department of Water Engineering and Management, University of Twente, the Netherlands 1987-: Associate Professor at the Department of Business, Public Policy and Technology, University of Twente, the Netherlands 1984- 1987: Assistant Professor at the Department of Economics at the University of Groningen teaching public finance. 1978- 1984: Assistant Professor at the Department of Economics at the University of Groningen teaching regional economics 1975-1978: Environmental Research Centre, University of Groningen, the Netherlands.
Research expertise	Prior research by Anne van der Veen at the University of Groningen devoted attention to labour market research and regional economic analysis. He published on part time labour, labour supply functions, labour supply and unemployment and on commuting. At Twente University he changed his subject to public policy issues. For the Province of Overijssel he designed a survey to build a multi regional Input-Output Table. With this model economic structure analysis was performed to evaluate public policy issues. Moreover, in collaboration with the Department of Civil Engineering he participated in the EU projects EPOCH, DELOS and RICAMA with contributions to Cost Benefit Analysis and Contingent Valuation for coastal zone management problems. Based on these EU projects Contingent Valuation became a central focus in research A third issue was research to evaluate the consequences of land use change for coastal areas. Agent Based Modelling was applied to set up a framework enabling the explanation of urbanization and sprawl. In current research attention is paid to: • Designing guidelines for Contingent Valuation Research within the EU project Floodsite. • Adaptive water management within the EU project Newater. • Mental models and frames within decision support models • Risk perception within cost-benefit analysis
10 key publications	1. Bočkarjova, M., A. E. Steenge and A. van der Veen (2004). Flooding And Consequent Structural Economic Effects;A Methodology. Flooding in Europe: Challenges and Developments in Flood Risk Management, Kluwer Academic Publishers. 2. Bočkarjova, M., A. E. Steenge and A. van der Veen (2004). "On Direct Estimation of Inital Damage In the Case of a Major Catastrophe: Derivation of the "Basic Equation"." Disaster Prevention and Management: An International Journal 13 # 4: 330-337. 3. Bočkarjova, M., A. E. Steenge and A. van der Veen (2007). Flooding and consequent structural economic effects; A methodology. Flood Risk Management in Europe Innovation in Policy and Practice. S. Begum, M. J. F. Stive and J. W. Hall, Springer. 25: 131-154. 4. Bockarjova, M., van der Veen, A. and Geurts, P.A.T.M. (2009) Reporting on flood risk perception in The Netherlands : an issue of time, place and measurement. Enschede, ITC, University of Twente, 2009. ITC Working papers series 1, 19 p. ISBN: 978-90-6164-278-7. http://www.itc.nl/Pub/Home/library/Academic_output/Working_papers_series.html 5. Bockarjova, M., van der Veen, A. and Geurts, P.A.T.M. (2009) A PMT - TTM model of

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	protective motivation for flood danger in the Netherlands. Enschede, ITC, University of Twente, 2009. ITC Working papers series 3, 23 p. ISBN: 978-90-6164-279-4. http://www.itc.nl/Pub/Home/library/Academic_output/Working_papers_series.html 6. Filatova, T., D. Parker and A. van der Veen (2009). "Agent-Based Urban Land Markets: Agent's Pricing Behavior, Land Prices and Urban Land Use Change." Journal of artificial societies and social simulation 12(1): 3. 7. Kolkman, M. J., M. Kok and A. van der Veen (2005). "Mental model mapping as a new tool to analyse the use of information in decision-making in integrated water management." Physics and Chemistry of the Earth 30/4-5: 317-332. 8. Kolkman, M. J., A. van der Veen and P. A. T. M. Geurts (2007). "Controversies in watermanagement." Environmental Impact Assessment Review 27(7): 685-706. 9. Polomé, P., S. Marzetti and A. van der Veen (2005). "Economic and social demands for coastal erosion protection." Coastal Engineering 52: 819-840. 10. Raaijmakers, R., J. Krywkow and A. van der Veen (2008). "Flood risk perceptions and spatial multi-criteria analysis: an exploratory research for hazard mitigation." Natural Hazards(DOI 10.1007/s11069-007-9189-z.). 11. van der Veen, A. (2004). "Disasters and economic damage: macro, meso and micro approaches." Disaster Prevention and Management: An International Journal 13#4: 274-280. 12. van der Veen, A. and C. J. J. Logtmeijer (2005). "Economic hotspots: visualising vulnerability to flooding." Natural Hazards 36(1-2): 65-80.

nr. 13 CV leading researcher	
Name and titles	Ir. J.A. (Jeroen) Veraart
Affiliation	Wageningen University and Research Centre, Environmental Sciences Group, Earth System Science and Climate Change
Academic/professional career	2001 - … Researcher Earth System Science and Climate Change Group (Alterra, Wageningen UR, www.ess.wur.nl) 2001 – 2003 Scientific support officer International Secretariat "Dialogue on Water & Climate 2004 – … Scientific programme officer of the national Research programme 'Climate changes spatial planning' 1999 – 2001 Researcher/lecturer Environmental Systems Analysis Group, Wageningen University 1994-2000 MSC Environmental Sciences with specialisation Aquatic Ecology and Water Quality Management (Wageningen University, the Netherlands) 1988-1994 VWO Atheneum-B, Norbertus Lyceum, Roosendaal, the Netherlands Member of "*The Albufera International Biodiversity group* (TAIB), Board Member of the Foundation for Sustainable Development (2000-2007). Several scientific publications and contibutions to books (see key publications), a lot of publications and presentations dedicated about science for a broader public and numerous scientific reports.
Research expertise	Ir J.A. (Jeroen) Veraart (1975) holds a MSc degree in Environmental Sciences from Wageningen University (2000) with specialisations in Aquatic Ecology, Water Quality Management and Environmental Studies. His work currently focuses on climate change and adaptation strategies within water management and biodiversity conservation. His on-going partime PhD-research aims to develop a method to map (un)certainties between scientific and practical experts regarding long term freshwater availability in coastal zones both qualitatively, through analysis of cultural concepts, and quantitatively, by statistical analysis.
10 key publications	1. Veraart J.A., Bakker M. (2009). Climate-proofing. Chapter 8, pp.109-122. In Ludwig F., Kabat P., Schaik H. van, Valk M. van der, 2009. Climate change adaptation in the water sector. Earthscan, London. (reviewed book chapter). 2. Kabat, P., Vierssen, W. van, Veraart, J.A., Vellinga, P., Aerts, J. (2005). Climate proofing the Netherlands. Nature, vol. 438, p. 283-284. (commentary). 3. Veraart J.A., Leemans R. (2005). Hoe verandert de Natuur. Wat merkt de landbouw van klimaatverandering? In: Bresser, A.H.M. et al. (eds), 2005. Effecten van klimaatverandering. Bilthoven : Milieu- en Natuurplanbureau, MNP-rapport 773001034.ISBN 90 69 60132 (reviewed book chapter). 4. Veraart J.A., Groot R.S. de, Perello G., Riddiford N.J., Roijackers R.M.M. (2004). Selection of (bio)indicators to assess effects of freshwater use in wetlands a case study of s'Albufera de Mallorca, Spain. Regional Environmental Change.Volume 4, Numbers 2-3,pp 107 - 117. (peer reviewed journal) 5. Veraart J.A., Ierland, van E.C., Werners S.E., Verhagen A., Groot, R.S. de, Kuikman P., Kabat P. Assessment of stakeholder and scientific expert judgements regarding adaptation strategies to climate change in water management in the Netherlands. Journal of Environmental Planning and Policy (submitted 2009). 6. Kabat P., Schulze R.E. Hellmuth M.E., Veraart J.A. Lenton R., (2002). Climate Variability and Change and Freshwater Management. International Review for Environmental Strategies. Vol 3, No 2, pp. 294-302. (peer reviewed journal) 7. Vries, A., de, Veraart, J., Vries, I. de, Oude Essink, G.H.P., Zwolsman, G.J., Creusen, R., Buijtenhek, H.S. et al. (2009). Demand and supply of fresh water in the South-western part of the Netherlands : an exploratory investigation (in

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	Dutch). Meta-studie Zuidwestelijke Delta, Kennis voor Klimaat, 82 p. 8. Veraart, J.A., Kabat, P. (2005). Klimaat verandert ruimtelijke ordening in Nederland. Geografie, vol. 14, p. 36-38. ISSN 0926-3837 (reviewed article for broader public) 9. Kabat P., Schaik H. van, Hellmuth M.E., Bates B., Bullock A. Connor R., Veraart J.A., Hoff H., Alcamo J., Schulze R.E., Droogers P. (2003). Climate changes the water rules. How water managers can cope with today's climate variability and tomorrows climate change.Int. secretariat of the Dialogue on Water and Climate, Wageningen the Netherlands (ISBN 90-327-0321-8). 10. Kabat P., Schulze R.E., Hellmuth R.E., Veraart J.A. (editors) (2003). Coping with Impacts of Climate Variability and Climate Change in Water management: A Scoping Paper. DWCSSO-01 International Secretariat of the Dialogue on Water and Climate, Wageningen, the Netherlands (ISBN: 90.327.0319 6)

nr. 14 CV leading researcher	
Name and titles	Prof dr ir W.A.H. (Wil) Thissen
Affiliation	Delft University of Technology, Faculty Technology, Policy and Management, head of Systems and Policy Analysis group
Academic career	1973 Graduated (with honors) as engineer, applied physics/systems and control engineering 1973-1977 PhD Student, TU Eindhoven 1978-1980 senior scientist /assistant professor, University of Virginia, USA 1980-1985 Policy Analyst/Head of Policy Analysis Group, Dept of Public Works, (Rijkswaterstaat) 1985-1992 associate professor, TU Delft 1992- full professor and (founding) head, Policy Analysis group. He was a co-designer and co-founder of the innovative curriculum in Systems Engineering, Policy Analysis and Management, and fulfilled several leading functions in the TPM faculty since 1992, including member of the management team, deputy dean, and director for research. He presently co-directs the Multi-Actor Systems programme, and the subprogramme on flexible infrastructures of the NGI BSIK programme. He is a board member of the NWO institute 'SRON', and of the IEEE Technology Management Council, and served the IEEE Systems, Man and Cybernetics Society as board member, vice-president, and chair/host of their annual flagship conference, and twice received the IEEE SMC outstanding contribution award. He is a member of the editorial board of *Technological Forecasting and Social Change*, *Environmental Impact Assessment Review*, and *Impact Assessment and project Appraisal*. He further served on numerous committees; published in a variety of journals; was numerous times speaker and session organizer at conferences; reviews for many journals and NWO.
Research expertise	Theory and concepts of Policy Analysis System Dynamics Modelling Strategic Environmental Assessment Actor/network analysis models Dealing with uncertainties Application fields: Water provision and water resource management, Land use planning, Energy systems (in particular the power sector)
10 key publications	1. L. Kornov and W.A.H. Thissen (2000). Rationality in decision- and policy-making: implications for strategic environmental assessment. Impact Assessment and Project Appraisal, Vol. 18, 3, 191-200. 2. Thissen W.A.H., P.G.J. Twaalfhoven (2001).; Towards a conceptual structure for evaluating policy analytic activities. European journal of Operational Research, Vol. 129, 627-649, 3. Geenhuizen M S van, W A H Thissen; Uncertainty and Intelligent Transport Systems: Implications for Policy. International Journal of Technology, Policy, and Management, Vol. 2, 1, 5-19. 4. Thissen, W.A.H. and Herder, PM eds. (2003). Critical Infrastructures. State of the Art in Research and Application. Boston/Dordrecht/London: Kluwer Academic Publishers, 304 pp. 5. Wallington, Tabatha , Bina, and Thissen, WAH (2007). Theorising strategic environmental assessment: Fresh perspectives and future challenges. Environmental impact assessment review, 569-584.

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	6. Carton, L.J. and Thissen, WAH (2008). Emerging conflict in collaborative mapping: Towards a deeper understanding? Journal of environmental management, 1-11. 7. Lei, TE van der and Thissen, WAH (2008). Quantitative problem structuring methods for multi-actor problems: an analysis of reported applications. Journal of the operational research society, 60, 1198-1206. 8. Thissen, WAH and Herder, PM (2008). System of Systems Perspectives on Infrastructures. In Mo Jamshidi (Ed.), System of Systems Engineering (Wiley Series in Systems Engineering and Management) (pp. 257-274). Londen: John Wiley & Sons. 9. Hermans, Leon M. and Wil A.H. Thissen (2009). Actor analysis methods and their use for public policy analysts. European Journal of Operational Research 196, 808–818 10. Daalen, C. van, W.A.H. Thissen and A. Verbraeck (2009). Methods for the modelling and analysis of alternatives. Chapter 26 in: A.P. Sage, W.B. Rouse (eds.), Handbook of Systems Engineering and Management, 2nd edition, John Wiley & Sons Inc., New York, p. 1127 – 1169.

nr. 15 CV leading researcher	
Name and titles	Dr. J. (Koos) Groen
Affiliation	• Senior Hydrogeologist of Acacia Water BV, Gouda • Associate Professor at the Faculty of Earth and Life Sciences of the Vrije Universiteit Amsterdam
Academic/professional career	1994 – present: Associate Professor at the Faculty of Earth and Life Sciences of the Vrije Universiteit Amsterdam 2002 Ph.D. Hydrogeology, Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam 2000-present: Evaluation and process management of research projects in groundwater pollution/remediation (SKB-KIT member) 2009-present: Member of the SNOWMAN review committee 2nd tender European research applications.
Research expertise	• Processes in coastal and offshore groundwater: solute transport, salt water intrusion inization, isotope hydrology, hydrogeochemistry, paleogroundwater, exploration and management. • Processes in contaminated groundwater: assessment, solute transport, hydrogeochemistry, isotope hydrology. • applied geophysics, • groundwater exploration and management. Currently working on: National study into the process of salinization in polders of Netherlands, effects of climate change on land and water users and adaptive and mitigating measures Research on beach hydrology and submarine groundwater discharge along the Dutch coast with TDEM geophysics, CPT divers and cone penetration & conductivity logs.
10 key publications	1. Groen, J. (1998). Hydrogeological investigations in Suriname. In T. E. Wong, D. R. De Vletter, L. Krook, J. I. S. Zonneveld, and A. J. Van Loon (Eds.), The history of earth sciences in Suriname. Royal Netherlands Academy of Arts and Sciences, Netherlands Institute of Applied Geoscience TNO, 129-174. 2. Groen, J., Velstra, J. and Meesters, A.G.C.A. (2000). Salinization processes in paleowaters in coastal sediments of Suriname: evidence from δ37Cl analysis and diffusion modeling. Journal of Hydrology 234, 1-20. 3. Groen, J., Post, V. E. A., Kooi, H. and Hemker, C.J. (2000). Palaeohydrogeology of the sedimentary plain of Suriname. In: Proceedings TraM'2000 Conference on Tracers and Modelling in Hydrogeology, Liege Belgium. IAHS Publication No 262, 417- 424. 4. Groen, J. (2002). The effects of transgressions and regressions on coastal and offshore groundwater. Ph.D. Thesis Vrije Universiteit Amsetrdam, pp 192. 5. Kooi, H., Groen, J. and Leijnse, A. (2000). Modes of seawater intrusion during transgressions. Water Resources Research 36, 3581-3589. 6. Roling, WFM Van Breukelen, BM, Braster M, Goeltom, MT, Groen, J. Van Verseveld HW. (2000). Analysis of Microbial communities in a landfill leachate polluted aquifer using a new method for anaerobic physiological profiling and 16S rDNA based fingerprinting. Microbial Ecology 40 177-188 7. Kooi, H. and Groen, J. (2001). Offshore continuation of coastal groundwater systems; predictions using sharp-interface approximations and variable-density flow modelling. Journal of Hydrology 246, 19-35. 8. Post, V.E.A., H. Kooi, J. Groen & J.J. de Vries (2001). Modelling the influence of sea level change and geological processes on the distribution of fresh and salt water in the Netherlands coastal areas. Proc. SWICA M3, Morocco, 4 pp.

nr 16 CV leading researcher	
Name and titles	Dr. A.C. (Arjen) de Vries
Affiliation	• General manager of Acacia Water BV, Gouda • senior hydrologist of Acacia Water BV • Associate Professor at the Faculty of Earth and Life Sciences of the Vrije Universiteit Amsterdam
Academic/professional career	For his PhD Arjen worked as a researcher at the university of Groningen and was involved in different projects related to climate modeling and hydrology. After defending his PhD study, Arjen joined the international water resources department of IWACO, a Dutch consultancy firm in the field of water and environment, for which a number of international projects were carried out. In this job, he acquired a broad experience in integrated water resources assessment and management and with the application of Remote Sensing and GIS techniques in water resources assessment and management. In 2004 Arjen joined Acacia Water at the Vrije Universiteit Amsterdam (Faculty of Earth and Life Sciences). Acacia Water was privatized in 2008 and operates as an innovative and research oriented consultancy. Arjen is general manager of Acacia and carries out projects in the field of (ground) water management, both in the Netherlands and elsewhere.
Research expertise	Arjen de Vries has a broad background, with special reference to institutional and awareness aspects of (ground) water projects. He is accustomed to complex projects, both in terms of institutional and technical aspects and often in the role as project leader. His strengths are not so much specialist technical solutions, but in the arena of complex institutional settings finding appropriate solutions, both technical and institutional. Arjen utilizes both his technical background, and communicative and persuasion skills to carry out projects successfully. (ground)water management, Institutional and process aspect of water management.
Key publications	1. De Vries, A.C. et. al., 2009, Vraag en aanbod van zoetwater in the Zuidwestelijke Delta, KVK rapport KVK017/09. 2. Aerts, J., et.al., 2007, Robustness of Sand Storage Dams under Climate Change, Vadose Zone J., Vol. 6, No. 3 3. Lasage, R., J. Aerts, G.-C.M. Mutiso, A.C. de Vries, 2008. Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya, Physics and Chemistry of the Earth 33; 67–73 4. Velstra, J. and A.C. de Vries. 2008, ‘Een nieuwe kijk op verzilting biedt perspectief voor het zoetwater tekort’. H2O, jaargang 41, nummer 22, pagina 20-21,

nr 17 CV leading researcher	
Name and titles	Dr J.P. (Jeroen) van der Sluijs
Affiliation	• Department of Science, Technology and Society, Copernicus Institute for Sustainable Development and Innovation, Utrecht University..Heidelberglaan 2, 3584 CH Utrecht • Centre d'Economie et d'Ethique pour l'Environnement et le Développement" (C3ED), Université de Versailles Saint-Quentin-en-Yvelines
Academic carreer	2001 – present, Assistant Professor / Senior researcher (permanent position) Department of Science, Technology and Society, Copernicus Institute for Sustainable Development and Innovation, Utrecht University 2004-present Professeur Invité (fixed term) Centre d'Economie et d'Ethique pour l'Environnement et le Développement" (C3ED), Université de Versailles Saint-Quentin-en-Yvelines. 1997 – 2001: Lecturer/Researcher, Department of Science, Technology and Society, Utrecht University 1996 YSSP Fellow, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. 1991 - 1996 Ph.D. Candidate, Department of Science, Technology and Society, Utrecht University. 1991 Junior Researcher, Department of Science, Technology and Society, Utrecht University.
Research expertise	Dr. Jeroen van der Sluijs has a background in geochemistry (MSc, Leiden University 1990) and did his PhD on uncertainty management in climate risk assessment (1997). He has extensive research experience in the field of Uncertainty management, NUSAP, Uncertainty methods, Climate Risk Assessment, Resilience, Uncertainty-robust policy strategies, Expert Elicitation, Stakeholder Elicitation, and the Precautionary Principle. He leads the research sub-program "Energy and Global Change, dealing with risk and uncertainties" within the Copernicus institute. Track record: • h-index: 14, g-index: 22, total impact 631 citations (ISI Web of Science) • (Co)-author of 43 peer reviewed journal articles and about 21 peer reviewed book chapters and 72 other scientific publications. • 72 invited & key note lectures at international conferences in the past 5 years; • Senior Research Qualification Utrecht University (SKO) (granted 1-3-2005) • Senior Teaching Qualification Utrecht University (SKO) (granted 23-6-2008) • Supervisor/Co-promotor of 6 Ph.D. students; • Consultancy and (inter)national assessment studies for: European Union [Involved in various EU FP projects]; BSIK Research Program Climate Changes Spatial Planning [Project IC10: Framing climate change risk and benefits]; PBL (Netherlands Environmental Assessment Agency, formerly MNP) [Uncertainty Guidance, many NUSAP applications; Uncertainty Communication; Evaluation of Word Views in Sustainability Outlook; Evaluations of uncertainty communication practice, energy modeling, climate change adaptation under uncertainty, etc. Etc.]; RIVM (National Institute of Public Health and the Environment, The Netherlands) [Development of expert elicitation protocol for environmental health risk assessment]; Knowledge for Climate [Science-Policy interface]; EC-JRC (European Commission, Joint Research Centre, Ispra) [Post Normal Science]; SENTER NOVEM [Uncertainty analysis of Netherlands Greenhouse Gas Emission Inventory]; Netherlands Knowledge Platform on Electromagnetic Fields [Uncertainty in health risk assessment of exposure to electromagnetic fields from overhead powerlines]; UK Flood Risk Management Research Consortium [Uncertainty communication in flood risk forecasting and flood risk management]; IIASA (International Institute for Applied Systems Analysis)

nr 17 CV leading researcher	
	[Participatory use of integrated assessment models]; SEI (Stockholm Environmental Institute) [participatory integrated assessment]; Rathenau Institute; [Consensus and dissent in the climate debate; Dealing with uncertainty in the science policy interface]; US-EPA (United States - Environmental Protection Agency) [Uncertainty in environmental modeling; advice on development of Uncertainty Guidance]; VROMRaad (Advisory Council of the Ministry of Housing Physical Planning and Environment, The Netherlands) [Critical reviews of climate policy in policy plans NRP3 and NRP4]; inter alia IIASA (International Institute for Applied Systems Analysis), SEI (Stockholm Environmental Institute), EC-JRC (European Commission, Joint Research Centre, Ispra); RIVM, VROMRaad;
10 key publications	1. J.P. van der Sluijs, A.C. Petersen, P.H.M. Janssen, James S Risbey and Jerome R. Ravetz (2008) Exploring the quality of evidence for complex and contested policy decisions, Environmental Research Letters, 3 024008 (9pp) **[9x cited]** 2. J-C. Refsgaard; J.P. van der Sluijs; A.L. Højberg; P.A Vanrolleghem (2007), Uncertainty in the environmental modelling process: A framework and guidance, Environmental Modelling & Software, 22 (11), 1543-1556. **[36x cited]** 3. J.P. van der Sluijs (2007), Uncertainty and Precaution in Environmental Management: Insights from the UPEM conference, Environmental Modelling & Software, 22, (5), 590-598. **[19x cited]** 4. J-C. Refsgaard, J.P. van der Sluijs, J. Brown and P. van der Keur (2006), A Framework For Dealing With Uncertainty Due To Model Structure Error, Advances in Water Resources, 29 (11) 1586–1597. **[40x cited]** 5. P. Kloprogge and J.P. van der Sluijs (2006), The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Climatic Change, 75 (3) 359-389. **[9x cited]** 6. J.P. van der Sluijs, M. Craye, S. Funtowicz, P. Kloprogge, J. Ravetz, and J. Risbey (2005), Combining Quantitative and Qualitative Measures of Uncertainty in Model based Environmental Assessment: the NUSAP System, Risk Analysis, 25 (2). p. 481-492 **[29x cited]** 7. J.P. van der Sluijs (2005), Uncertainty as a monster in the science policy interface: four coping strategies. Water science and technology, 52 (6) 87–92 **[8x cited]** 8. Risbey, J., J.P. van der Sluijs, P. Kloprogge, J. Ravetz, S. Funtowicz, and S. Corral Quintana (2005): Application of a Checklist for Quality Assistance in Environmental Modelling to an Energy Model. Environmental Modeling & Assessment, 10 (1), 63-79. **[14x cited]** 9. W.E. Walker, P. Harremoës, J. Rotmans, J.P. van der Sluijs, M.B.A. van Asselt, P. Janssen, and M.P. Krayer von Krauss (2003), Defining Uncertainty A Conceptual Basis for Uncertainty Management in Model-Based Decision Support, Integrated Assessment, 4 (1), 5-17. **[85x cited]** 10. J.P. van der Sluijs, J.C.M. van Eijndhoven, B. Wynne, and S. Shackley (1998), Anchoring Devices in Science For Policy: The Case of Consensus Around Climate Sensitivity, Social Studies of Science, 28, 291-323. **[45x cited]** [between brackets number of citations according to ISI Web of Science cited ref search]

nr 18 CV leading researcher	
Name and titles	R.J.M. (Raymond) Creusen M.Sc.
Affiliation	TNO Built Environment and Geosciences, group water treatment, Laan van Westenenk 501, 7334 DT, Apeldoorn, The Netherlands
Academic career	1983-Msc. in Chemical Engineering, University Twente, Enschede
Research expertise	Separation processes, especially membrane technology for (waste water applications. This experience is built-up in a lot of projects varying in duration from several weeks to several years. Membrane technologies involved were mainly pressure driven technologies like reverse osmosis, nanofiltration, ultrafiltration and microfiltration. Aspects considered were: - application research with commercial available products - membrane development (reverse osmosis, nanofiltration) - the membrane development has resulted in a reverse osmosis membrane which is commercialized - module development (reverse osmosis, nanofiltration, ultrafiltration, microfiltration); the module development has resulted in a new type of spiral wound module (as projectleader involved, patent) and so called transversal flow modules. - Process development. Further activities include: TNO project manager of the nanofiltration part in European research project on treatment of bleach plant effluent (1990-1993). Responsible for handling the problem of dissolved solids in the TNO-CLRI cooperation programme for the Indian leather sector in the field of environmental technology (1992-1993). Project co-ordinator in an EU project focused on waste water treatment (1998-2000). Project co-ordinator in 2 large membrane separation related projects based on membrane contactor technology (EET, 2003-2007). Projectmanager of membrane based water treatment projects (2008-) Economical evaluations of processes. This experience is built-up by the evaluation of both membrane processes and other processes like e.g. fermentation processes, distillation processes, water treatment processes. Project management. This experience is built-up as project leader and project co-ordinator in large projects (EU and others) with many industrial) partners .
Key publications	1. Van Erkel, J. , P.M.M.C. Bressers and R.J.M. Creusen. Processes for separation of gases using ionic liqueids, EP 2016991, 2009. 2. Van Groenestijn, J.W., J.H.O. Hazewinkel, R.J.M. Creusen, K.P.H. Meesters. Recovery of suphuric acid, EP 1690828, 2007 3. Creusen, R.J.M., E.C.A. Hendriks and J.H. Hanemaaijer. Process and device for the separation of an unsaturated hydrocarbon from a fluid mixture with other hydrocarbons, EP0634204, 1996 4. Creusen, R.J.M., F.F. Vercauteren, Semipermeable composite membrane, EP 0532687, 1994