Perspectief round 2019/2020
Phase 3: Program application

AquaConnect

Key technologies for safeguarding regional water provision in fresh water stressed deltas

P19-45

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Content

1 Overview

1.1 Title

AquaConnect – Key technologies for safeguarding regional water provision in fresh water stressed deltas

1.2 Public Summary

The Dutch delta faces enormous challenges in fresh water provision for industry, agriculture and nature during increasingly frequent severe droughts due to climate change. This requires a major overhaul towards a water system that stores precipitation surplus instead of discharging it to the sea and uses alternative water sources. AquaConnect is instrumental in this transition by developing: i) chemical technologies enabling use of domestic/industrial effluents and brackish (ground)water, ii) digital technologies to design smart grid infrastructures to connect supply, demand, and nature based storage, iii) tools to manage related societal changes, and iv) demonstrations in four utilisation cases and international twinning.

AquaConnect:

- connecting waters by chemical and digital key technologies, models and infrastructures;
- connecting water quantity and quality;
- connecting man-made and natural water systems;
- connecting partners in various science disciplines and in institutions of practice;
- connecting national programs and multiple pilots;
- connecting national upscaling to international outreach.

1.3 Program leader and representatives from user group

Program leader:

Prof. dr. ir. **Huub H.M. Rijnaarts**, Wageningen University & Research

User representative(s):

Paul Roeleveld (Royal Haskoning DHV), **Wilbert Menkveld** (Nijhuis Technologies), **Johan Driessen** (Vitens), **Karin Lekkerkerker** (Dunea), **Henk Pool** (Dow Benelux), **Albert Janssen** (Shell Netherlands), **George Zoutberg** (Hoogheemraadschap Hollands Noorderkwartier), **Annemarie Kramer-Hogendoorn** (Water authority Rijn en IJssel), **Klaasjan Raat** (KWR Water Research Insitute), **Alexander Laarman** (AMS), **Thecla Westerhof** (Province of Zeeland).

These end users participate in the AquaConnect steering board in which Prof.dr. **Annemarie van Wezel** represents Universities, **Hans van Duijne** represents Deltares and WenR and **Hans Cappon** represents HZ.

1.4 Participating organisations

Research institutes

Research institute	Department / research group
Wageningen University & Research (WUR)	Environmental Technology / subgroup Water Technology Environmental Technology / subgroup Systems Engineering Soil Physics and Land Management / subgroup Ecohydrology
University of Utrecht (UU)	Landscape Functioning, Geo-computation and Hydrology Department of Law/Utrecht Centre for Water, Oceans and Sustainability Law
Eindhoven University of Technology (TU/e)	Electrical Engineering / Electronic Systems Electrical Engineering / Control Systems
Delft University of Technology (TU/D)	Water Management
University of Twente (UT)	Membrane Science & Technology
Vrije Universiteit (VU)	Environmental Policy Analysis
University of Amsterdam (UvA)	Institute for Biodiversity and Ecosystem Dynamics, Freshwater and Marine Ecology
Deltares	Water and subsoil resources

Wageningen Environmental Research (WENR)	Climate, water and spatial planning / nature-based solutions
HZ University of Applied Sciences (HZ)	Water Technology

Involved (end)users

Companies		
Royal Haskoning DHV	Vitens	Dow Benelux
Witteveen&Bos	Oasen	Shell
Nijhuis Industrial Technologies	Dunea	Swinkels
ICT Netherlands B.V.	Brabant Water	Stibbe
Evides	KnowH$_2$O	NXFiltration

Knowledge institutes	
KWR Water Research Institute	AMS Institute

Other organisations		
Ministry of Infrastructure and Water Management	Water authority Vallei & Veluwe	STOWA
Province of South-Holland	Water authority Rijn & IJssel	North Sea Port
Province of Zeeland	Water authority Vechtstromen	GlastuinbouwNL
Province of North-Brabant	Water authority Scheldestromen	Water Alliance
Municipality of Terneuzen	Water authority Hoogheemraadschap Holland Noorderkwartier	Port of Rotterdam
Municipality of Amsterdam	Water authority Aa en Maas	Netherlands Water Partnership

1.5 Timing and costs

Requested budget NWO € 3.999.971.20	Cash contribution - € 1.418.750	In-kind contribution - € 996.380
Total program budget *(including in cash/in kind contributions & Governance) :* € 6.415.101	Program duration – 4.5 years	This program consists of ☒ A project with 6 work packages (WP 2-7) and a Governance project (WP 1) ☐ *xx* projects and a Governance project

Position*	WUR	UU	TU/e	TUD	UT	VU	UvA	Deltares	WENR	HZ	Total
Number of PhD students	5	3	1	1	1	1	1				13
Number of postdocs (2 yrs)	2	1	1			1	1				6
Researchers at TO2 and University of applied sciences								150k€	150k€	200k€	

* See section 1.4 for abbreviations of universities, research institutes and universities of applied sciences

2 Summary

2.1 Summary

The Netherlands and other delta regions experience increasing threats to fresh water provision essential for ecosystems and societal functioning, including industrial and agricultural production. AquaConnect develops new scientific concepts for solutions that can **ensure future fresh water provision**. New **key digital and chemical technologies, and innovative water governance** approaches are developed that together form the base to design **regional self-sufficient fresh water provision grids**. **Digital technologies** are local scale modeling and design tools that allow identification and use of unexploited water resources and subsurface water storage. These are needed to design and operate new infrastructural grids (including pipelines, waterways, digital connections) to match water demand and supply. **Physical-chemical treatment technologies** – based on nanofiltration and electrodialysis - will be developed and combined with existing technologies to enable use of brackish groundwater and wastewater treatment plant effluents. Water quality targets will be defined from risk assessments of circular water systems, considering technological and in situ biological removal of emerging pollutants and sustainable management of sludges and brines. Whilst closely working with stakeholders in four utilization cases (Zeeuws-Vlaanderen, South-Holland, Higher Sandy regions, Amsterdam Region), due attention will be paid to **societal feasibility**, and the value of freshwater for the regional economy. Special focus will be on how to dovetail **policy, legal, cultural change**, **and perception issues** with the new technologies. Demonstration activities aim for **further upscaling and a co-creative international outreach program**, exporting technological approaches and sharing know-how on system management, governance and cultural change.

2.2 Unique selling point(s)

i) Ensuring future fresh water provision and drought-resistant water systems developed by a team of multi-disciplinary scientists;
ii) Connection with 37 key stakeholders contributing cash and in-kind;
iii) Key digital technologies to design and control local producer-to-consumer water grids and nature-based water buffering;
iv) Risk-assessment for circular water systems, setting targets for treatment of effluents, brine and sludge;
v) Key chemical technologies enabling further intentional use of effluents and brackish water;
vi) Hands-on water governance insights, addressing economic, legal, policy, perception and cultural issues;
vii) Four demonstration areas integrating water systems, treatment and governance, for national upscaling and global outreach.

2.3 Keyword(s)

Drought; Water re-use; Smart water-grids; Water distribution modelling, design, optimization and control; Fit-for-purpose water treatment; Brine management; Cyclic water system risk assessment; Water governance.

3 Program

3.1 Problem and vision of success (Impact)

Problem Analysis. The Netherlands, and delta's worldwide, are increasingly threatened by freshwater scarcity as a result of an increased water consumption, climate change related droughts and saltwater intrusion[1,2]. These result in seasonal fresh water shortages for ecosystems, agriculture, industry and even municipalities. Formerly, the prime concern for deltas was protection against floods with dikes, levies, flexible (ship) locks and a water infrastructure designed for fast discharge of excess rainwater to the main rivers and sea[3]. More recently, with the years 2018, 2019, and 2020 as the most extreme examples, water scarcity occurs for four to eight months a year[4]. Therefore, the traditional "Delta strategy" needs to be adjusted to increase fresh water availability during droughts. Local producer-to-consumer water grids, nature-based water buffering and treatment and technologies will urgently be needed to achieve this. This will include storing of wet-season surpluses and (re-)use of all water sources available, including currently ignored nonconventional water resources. These nonconventional water resources, such as industrial and domestic effluents and brackish groundwater, are available year-round, and help to overcome water shortages. This will constitute a major technical and societal transition that AquaConnect (AC) aims to address.
All these ideas are to be transferred into new and climate robust strategies for regional fresh water provision of deltas. Water authorities, drinking water companies and (agro)industrial end-users recognize the increasing fresh water scarcity problem, and the potential of excess water buffering and (re)using nonconventional water sources. However, they are confronted with technical and societal barriers, and missing scientific knowledge to resolve these[5]. Missing scientific knowledge includes limited insight in i) the relationships between cause and effect in the water system; ii) local system interactions and influences of external factors (climate change, water use); iii) and adequate governance to manage the water system. AquaConnect aims to provide new scientific and technological knowledge on the potential of using nonconventional water sources. This includes wide scale (subsurface) water buffering; safety and sustainability of the use of nonconventional water sources[6], including tailored treatment to deliver adequate qualities for use of water, brines and sludges[7]. Moreover, answers to how to connect regional water demand and supply with physical and digital infrastructure complementary to current water grids[8] will be provided. In addition, socio-economic, legal, governance, cultural and perception related to alternative water source (re-)use and natural system storage[9,10] will be assessed. AC aims to support this transition on three levels: on the water system, with digital technologies, on water technology and infrastructure, with digital and chemical technologies, and on the societal/cultural level, with new governance approaches.

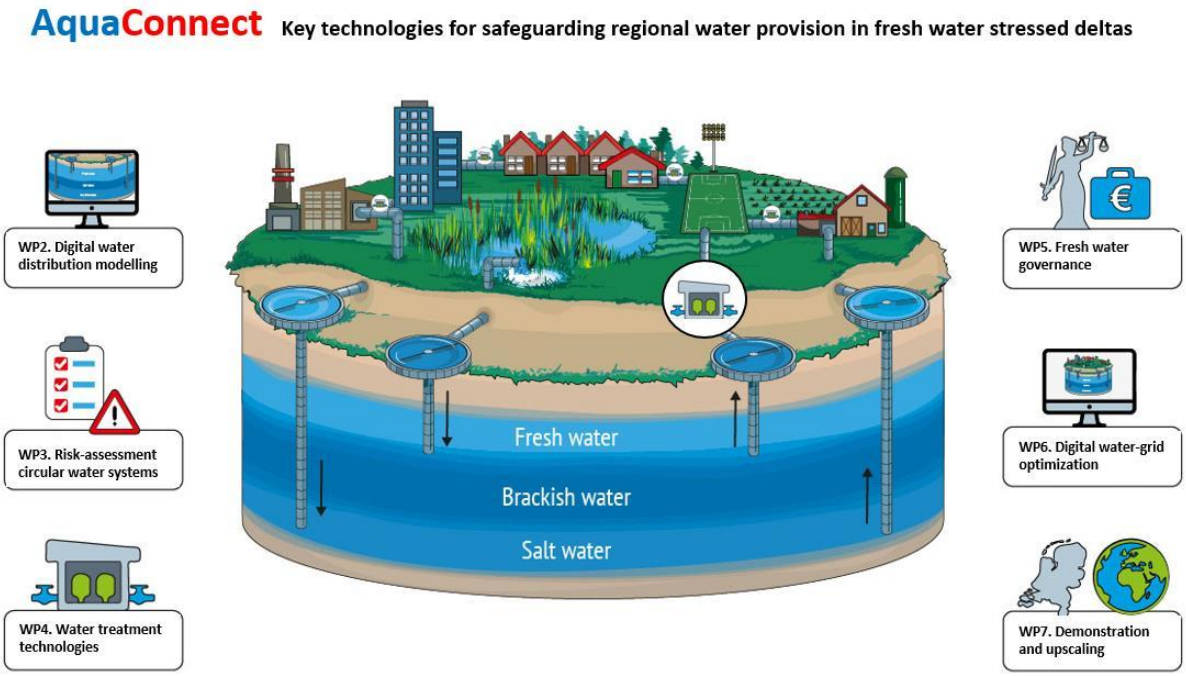

Figure 1. The AquaConnect smart water-grid and work packages of AquaConnect

The Proposition. The proposed solution for safeguarding regional fresh water provision is a smart water-grid (Fig. 1) that safeguards regional self-sufficient water supply (so off the national grid and into a regional grid) by connecting current demand of water of certain minimal quality to available supply of that quality. To cope with fluctuations in natural water quantity and quality under weather variability and extremes, such a grid is supported by i) increased storage capacity underground; ii) the use of nonconventional and marginal (brackish, effluent) water resources by treatment including energy efficient desalination. To design and operate such a grid we need: a) digital technologies

(modelling of the naturual system and storage impacts, system models to design and optimize the grid); b) chemical technologies (treatment and monitoring); c) overcome ecomomic, governance and legal and cultural/perception boundaries to make the transition.

Knowledge gaps. To *ensure future fresh water provision and obtain a drought-resistant water provision system in the form of a smart water-grid* the scientific knowledge gaps are: i) unclear and uncertain a) availability of nonconventional water sources, b) potential of subsurface water storage, c) possibilities for the water network for delivering water from the supply resource to the demand centres, and d) dynamics of brackish water extraction and underground brine disposal (targeted in AC scientific workpackage 2 (WP2), (Fig. 1)) ii) unknown quality requirements for different water re-use schemes in a circular -re-use based- water system (WP3), associated with a lack of cost effective technologies for treatment that can tailor quality to these requirements and prevent new problems with brines and sludges (WP4), iii) a lack of insight in the economic value of freshwater availability for regional economics, appropriate and effective governance and legal arrangements, and societal/cultural dynamics relevant for upscaling (WP5), and iv) lack of design instruments to test the feasibility and economics of adaptations in local water infrastructure (smart water grids, infrastructure needed to bring the water from sources to the end users in industry, agriculture or nature conservation) (WP6), and v) a lack of integrated demonstrations with stakeholder inclusion, which is the most convincing tool for further integration, national upscaling and international outreach (WP7).

Pathway to Impact. AquaConnect aims to improve understanding of -and ways to resolve- these barriers, scientifically, technologically, and from a societal perspective, in an integrated and scientifically coherent way. AC will contribute to a paradigm shift in fresh water provision in The Netherlands: from "discharging precipitation surplus and effluents to main rivers and the sea as quickly as possible to prevent flooding" to "storing and reusing water to arrive at drought resilient and regionally self-sufficient fresh water provision". This will be accomplished by generating new scientific technological and governance insights. Our technology-supported-by-governance approach can be adopted in other water scarce deltas across the globe, thereby creating opportunities for export. The AC pathway to impact (Fig. 2) is accomplished by linking scientific research work packages to four stakeholder groups/case & utilization studies in different regions of The Netherlands (Table 1) with generic and region-specific water provision problems (Fig. 2, deliverable A), ensuring the transfer of **scientific insights and technical innovations** to demonstration **and practical outcome**.

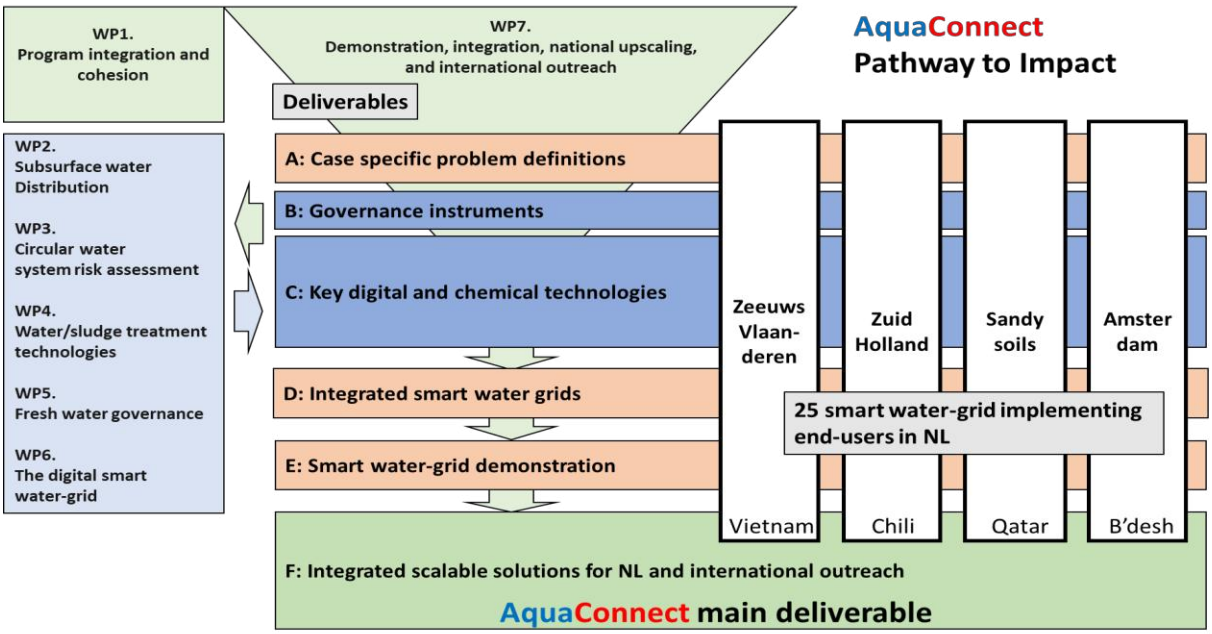

Figure 2. AquaConnect pathway to impact combined with workpackage structure, deliverables, and case study regions

The technological outcomes of the scientific work packages 2-6 (Fig. 2, deliverables B & C) are toolboxes of key-technologies (digital and chemical), risk assessment methods for circular water systems defining sustainable applications (including that of the treated water, and co-produced sludges and brines), and science-based guidelines for adapting accompanying social/economic/legislative instruments to maximize impact. These will be integrated by analyzing the contextual and generic character of four regions typical for deltas and creating integrative solutions, based on smart water grids using storage technology and nonconventional water resources to safeguard regional provision for industry, agriculture and nature (Fig. 2, deliverable D). By demonstrating these with the stakeholders (Fig. 2, deliverable E), we aim for end-project and post-project continuation and upscaling, and set an example function for other regions in NL and globally, all leading to impact: a changed water provision management put in practice and accepted by society (Fig. 2, deliverable F). The four case study areas and the international outreach and their links to the scientific work packages are described below.

Table 1. AquaConnect case-study regions in The Netherlands

Case-study region	Characteristics and aim of AquaConnect
Zeeuws-Vlaanderen	• Limited water storage capacity due to geomorphological and geohydrological constraints. • Water import from Rhine/Meuse to overcome local water shortage, which was insufficient during recent droughts and negatively impacted industry and agriculture. ➔ Aquaconnect will i) provide digital tools to enhance the regional water storage capacity (WP2); ii) combine these with risk-assessment tools (WP3) and new water treatment technologies (WP4) in a regional smart water-grid (WP6) in collaboration with regional stakeholder-group 'Robust Water Management Zeeuws-Vlaanderen', supported by an assessment of legal boundaries and governance arrangement on regional and cross-border scale (WP5)
Amsterdam Metropolitan Region	• Densely urbanized and economically important region that is increasingly affected by climate-change related drought and salt water intrusion into surface water and groundwater. ➔ AquaConnect will provide innovative water-treatment technologies (WP 3&4) within a smart water-grid that allows i) the production of water for industry or storage in dune subsurface area (related to the 'Water Factory' project of wastewater treatment facility 'Wervershoof' of stakeholders HHNK, PWN) and ii) the use of treated water for irrigating Amsterdam city parks.
Higher Sandy Soils	• Hosts extensive agriculture, (agro)industry, the largest nature conservation areas of The Netherlands and preserves an important part of the national fresh groundwater stock. • The region is designed to transport surplus precipitation as quick as possible to prevent flooding, while the droughts in 2018, 2019 and 2020 resulted in substantial decline in stream discharge and groundwater levels, with detrimental impact on agriculture and nature. ➔ AquaConnect will i) develop an assessment-tool for regional redesign (WP6) that transforms the water system in a water-buffering water-grid by identifying locations for storage of unconventional water resources, incorporating cyclic water system risk-assessment (WP3) and innovative water treatment technologies (WP4) to protect the water-buffer against contamination with micropollutants; ii) define the new responsibilities for water users and water-producers within this regional water-grid (WP5).
Province of South-Holland	• Home to 3.5 million people, Rotterdam port and a large agriculture/horticulture sector. • Groundwater extraction, land subsidence, salinization and population growth put pressure on the fresh water availability, while surplus fresh water is discharged to sea. ➔ AquaConnect will i) identify the possibilities for brackish water extraction and subsurface brine injection (WP2), industry water-cascading in a smart water-grid (WP6) and reuse of treated wastewater as a result of innovative treatment technologies (WP4), taking into account quality risks in circular water systems (WP3) and the subsurface (WP4) and the legal and administrative boundaries of using nonconventional water resources (WP5).
Global outreach building on existing international relations	➔ AquaConnect will assess the sustainability of effluent, sludge and brine reuse in Qatar (WP4) as part of the 'Greening the Dessert Program' of Shell and academic partners (twinning case Higher sandy Soils), delivering extreme boundary conditions for implementing circular water-grids (WP6), accounting for different cultural perceptions of water-reuse in governance (WP5). ➔ AquaConnect will build on existing work of Deltares and WUR in Chile (twinning with case South Holland) to identify locations to capture precipitation surplus (WP5) to overcome dry periods. Treatment before storage (WP3 / WP4) and water ownership and responsibilities (WP5) are important issues after storage. ➔ AquaConnect will exchange scientific knowledge in running projects in Vietnam (NWO-UDW ENTIRE, circular water management of three industrial parks in Ho Chi Minh City Region), in twinning with case Zeeuws-Vlaanderen, and Bangladesh (NUFFIC, reuse of wastewater for agricultural irrigation in Bengal cities), in twinning with case Amsterdam, irrigating parks.

Vision of Impact. The problems with fresh water provision in the four demonstration cases are symptomatic of the current and future fresh water provision that can be and will be found in many deltas around the world. It illustrates the urgency of finding solutions for safeguarding self-sufficient regional water supply that are both generally applicable to many deltas yet sufficiently flexible to be optimal for a given case. AquaConnect (AC) will provide the scientific knowledge needed for these generic yet flexible solutions in the form of climate-robust smart water-grids for regional water management, for which AC creates innovative new digital and chemical technologies and governance approaches. **These newly-developed digital and chemical technologies (delivered in year 1– 3) will be validated and demonstrated in pilots and smart grids in ongoing and new case-studies (in year 2–4), offered by the regional stakeholders (regional authorities, water authorities, drinking water companies and water end-users) (in year 1–3) in the four earlier described Dutch regions in close collaboration with research institutes.** Scientific analyses of socio-economic and legal instruments in close cooperation with local, regional and national authorities (in year 1–3) will

facilitate the smooth full-scale implementation of the newly developed key technologies (in year 2- 4). Business models for these newly developed technologies will be assessed together with technology-suppliers and consultancies (year 4–4.5 = end of AC). **Ultimately, this will lead to an AquaConnect toolbox of proven technologies that can be used for the scaling up of smart water-grids throughout The Netherlands** (year 4–4.5 plus post-project), and demonstrated on pilot to full scale internationally (year 4–4.5, plus post project) by companies involved in AC.

3.2 Objectives and technical & scientific challenges

The main challenge (in general) is that currently sub-systems for alternative water provision are invented and optimized to cope with increasing droughts. AC needs to consider the entire water system, including buffers, infrastructure, users and prosumers, and the management of that system through governance and infra structures, which are supported by adequate data, treatment and knowledge about boundary conditions and constraints (legal, societal, economic). During the co-design phase of the AquaConnect research-proposal together with regional authorities, water authorities, drinking water companies, technology-providers, research institutes and water users, several scientific knowledge gaps and challenges related to missing modeling and water treatment technologies and missing legal and governance instruments were identified (section 3.1) for which increased scientific insights are needed in service to the realization of a regional smart water-grid containing key-technologies in the case-study regions. The overarching theme of AC is a nationwide water provision system vision, including the novel technologies developed, which can only be demonstrated in regional context and then adopted by other regions, as we call here smart water grids. As a result, the following scientific objectives and scientific output of the 5 scientific WPs of AC were determined (Table 2).

Table 2. Scientific challenges and objectives of AquaConnect

WP	Scientific challenge	Objective
WP2	- Numerical models to support the design of smart water-grids needed to be able to couple regional scale impacts to local solutions. Such models are currently not available. - Limited insights in the effect of brine injection and brackish groundwater extraction on subsurface water distribution. - Methods for the operational monitoring and management of underground fresh-saline groundwater resources are lacking.	- To develop seamlessly scalable (between regional and local scale) groundwater-surface water models including salinity that calculate current and future subsurface water distribution and storage possibilities: WP 2.1. - To experimentally determine the effect of brackish water extraction on subsurface water distribution: WP 2.1. - To design a generic toolbox to support the management of underground water storage and extraction by data-model assimilation: WP 2.2.
WP3	- Limited insight in occurrence and fate of the mixture of unknown, hydrophilic compounds that easily circulate through the water cycle. - No comprehensive understanding of the fate of compounds in subsurface water systems. - Existing risk assessment tools do not comprehensively assess circular water systems where re-use can affect human and environmental health.	- To experimentally determine the fate of chemicals in groundwater systems used for water storage, as input for WP 3.1: WP 3.2. - The development of risk-assessment strategies that can identify potentially harmful chemicals in cyclic water systems, which provides input for fit-for-purpose water treatment (WP4) and legislation around cyclic water reuse (WP5): WP 3.1. - To assess the impact of water reuse instead of discharge on biodiversity using the NWO research infrastructures ARISE[11] and UNLOCK[12]: WP 3.1.
WP4	- Water treatment technologies that allow selective removal of specific pollutants are currently insufficiently developed for full-scale application, in a water-on-demand contex. - Current sustainability assessment frameworks for brine and sludge treatment and reuse only incorporate a limited set of contaminants.	- To develop a configuration of electrodialysis and nanofiltration that can selectively remove target chemicals (WP 3) from diverse water streams: WP 4.1. - To broaden currently existing sustainability frameworks with newly identified chemicals of risk in circular water systems (WP 3) using modelling and field-experiments that predict the quality effects of reusing or disposing residual streams on soil, surface water and groundwater, setting treatment targets: WP 4.2.
WP 5	- Lack of awareness of meaning of freshwater availability for the regional economy.	- To develop models and calculate the economic value of freshwater for the regional economy: WP 5.1.

	- Complex policy and legal frameworks designed for linear resource systems, not allowing circularity thus blocking effluent and brackish water reuse. - No knowledge of alternative frameworks that secure economic viability, ecological integrity, but need institutional changes and inclusion of societal perceptions. - No insight into non-technical societal factors needed for upscaling from a pilot/demonstration phase to a national and global level.	- To map policy and legal frameworks that guide water provision in a comprehensible way: WP 5.2. - To develop insight in alternative frameworks that exist elsewhere on the global and that secure economic viability, ecological integrity and societal perceptions issues: WP 5.3. - To study how upscaling issues (including perception matters) have been addressed elsewhere to upscale technologies: WP 5.3.
WP 6	- A lack of knowledge on how to computationally formulate and optimize adaptive integrated local water grid system with uncertainty. - No tools for the redesign of local and regional water networks to improve water availability taking into account uncertainty in availability of data associated with different land uses, hydrological water system organization and the hydrogeological system. - Lack of analytical methods and deployment framework for the real-time monitoring and optimal decision-making of newly developed smart water-grids delivering water to wide range of future demand profiles.	- To develop a decision-support tool for water-grid optimization that can generate a climate-robust water system, based on new water sources (WP2), associated risks (WP3), new technology (WP4) and institutional, socio-economic and legal constraints (WP5): WP 6.1. - To develop a monitoring and closed-loop control framework for local smart water-grids based on distributed model predictive control and artificial intelligence: WP 6.2. - To develop a decision-support tool for regional authorities that allows regional redesign to include all potential water users, including the environment: WP 6.3.

3.3 Sense of urgency and uniqueness of the proposed program

The Dutch Delta was thought to be safe for decades due to its extensive flood-protection measures during the last 60 years. In the last 10 years, a new annual threat has become apparent requiring adaptation urgently: a seasonal shortage of fresh water accompanied by falling water tables[13], salinization of coastal surface and groundwater[14] and reduced river discharges, stressing horticultural/agricultural, industrial, domestic and nature conservation sectors[15]. The occurrence of dry spring and summer seasons in 2018, 2019, and 2020 has indicated the urgency for acting now and provided the political motivation to initiate national drought strategies to supplement the already existing "Deltaplan zoetwater" (Delta plan for fresh water management)[16]. These strategies are predominantly aimed at fresh water provision through the larger water distribution ways of The Netherlands, which depend on the main river discharges. Areas remote from this main Rhine/Meuse tributary system are connected by channels and pipelines to it, with central storage facilities, such as in the "Biesbosch basins", adaptive level controlled Markermeer, or subsurface reservoirs in dune infiltration areas. However, these connections can neither fully resolve the water provision on the very local scale under the extreme drought conditions -currently and in the near future-, nor mitigate the increased salinization of surface and groundwaters in coastal regions, nor prevent drought damage to agriculture and nature in the inland sandy soil regions. Other solutions than the traditionally centralized approach are urgently needed. AquaConnect responds to this urgency with a unique and different multidisciplinary and cross-institutional approach seeking the solutions by transformations in water provision and water storage on the local scale. For these solutions, AC delivers the missing knowledge to create alternative water resource based water grids in direct interaction with local stakeholders, a new and original approach crossing the boundaries of -and connecting the sector-wise organized- water institutions (Water authorities, drinking water companies, provinces, municipalities, ministries) with water demanding users (industries, agriculture/horticulture and nature conservation organizations). The generation of knowledge needed can only be done by a new and innovative multidisciplinary approach combining (hydro)geology, hydro-ecology, environmental chemistry and biotechnology, material science and water technology, digital and smart grid computer modelling technologies, and water governance, all in one team. By a strong inclusion of social sciences in interaction with stakeholders, we will design water provision grids in four case studies in NL that are up-front society supported, i.e. essential for scaling up nationally at the end and after the project. The in AC involved applied research institutes Deltares, Wageningen Research, KWR and HZ University of Applied Sciences, are essential in connecting to practice and future scaling up. The integrated approach and the individual technologies we develop are also in themselves unique and providing groundbreaking new knowledge:

i) The socio-technological approach of WP5 combined with other WPs (as has been used in the creation of the proposal following Theory of Change and Routes to Impact methods) in direct interaction with key stakeholders gives a typical Dutch – and therefore an original scientific and practice integrated– approach which is essential in effectuating routes to impact, thus preventing the classical traps of "Disconnected Science and Technology Push" leading to science and technologies remaining unused after projects finish.
ii) Numerical models describing the saline-fresh groundwater distribution (WP2) needed to address the multi-scale impacts of climate change, underground water storage strategies and brine disposal are essential and a unique frontrunning expertise of UU/Deltares.
iii) Circular system risk assessments addressing compounds of emerging concern are -until this moment- absent in science and practice, and the new insights will give water authorities a firsthand in designing innovative and appropriate quality regulations (UvA/WUR, WP3).
iv) Treatment technologies (WP4) achieve tailored water quality and as well addressing qualities of brines and sludges for their sustainable use, are highly original and needed in (inter)national applications (WUR/UT).
v) The smart water grid technologies (WP6) are very innovative, building on projects Water Nexus (Perspectief 2015, WUR/TUD) and smart grid engineering know how (TUD/TU/E), and will be tailored to communicate with national water distribution models (in The Netherlands, the national hydraulic set of instruments (NHI)[17] and associated regional grid models (RTC)[18].
vi) The 4 national case-studies and 4 international twinnings are a new way of creating platforms for integration, national upscaling and international outreach.

AquaConnect is unique and original and it builds on and prevents duplication of other running large research programs, either completed or in their finalisation stage, such as Water Nexus[19], COASTAR[20], Lumbricus[21], and ADAPT-LOCKIN[22]. Water Nexus NWO Perspectief (2015-2021) studies water provision in an industrial setting, combining natural and chemical technologies for treatment of industrial effluents enabling reuse by the industry, and digital technologies to match water demand and supply, currently leading to pilots and upscaling by the industrial partners. A key outcome of Water Nexus is the need to expand the water grid from serving one industry only to multiple water users in the full region requiring additional stakeholders and new governance approaches, which are the topics of AC for the case Zeeuws-Vlaanderen. COASTAR TKI 2018-2020 performed feasibility studies done by KWR and Deltares for different measures concerning brackish water extraction and artificial recharge, specifically for the province of South-Holland. It showed the need for a better understanding on fresh/salt water interfaces in the subsurface (WP2) to assess effects of extraction/recharge measures on groundwater salt intrusion. Moreover, it indicated that new ways for brine management (WP 2 and 4) and groundwater policies (WP 5) are needed. Within the applied research program Lumbricus, solutions to improve the water availability for farmers and to decrease the pressure on groundwater resources in the Higher Sandy Soil regions have been developed, focusing on water holding capacity of soils and agricultural fields. Within AC, we expand to the full regional system (soils, surface waters, groundwater, wastewater treatment systems, storm water collection areas) with all water stakeholders included (provinces, drinking water companies, water authorities) to redesign landscapes from the perspective of "smart water grids" for all water depending parties (WP6). Especially water quality (compounds of emerging concern, and effects of brines and sludges) in a circular water system are studied in AC (WP3, 4). ADAPT-LOCKIN studied governance processes that block innovation, and the results feed in nicely in AC governance WP5. In addition, AC is compatible with new research initiatives related to fresh and salt water management (e.g., Dunea's FRESHMAN pilot[23]), KLIMAP[24] and SALTISolutions[25]. The objective of KLIMAP (TKI 2020-2024) is to develop tools and transition pathways to climate-proof design, use and management of the water and soil systems for (circular) agriculture and nature in the Dutch Higher Sandy Soils region. Especially the key chemical and digital technologies and the governance approach of AC are complementary to KLIMAP. SALTISolutions (NWO perspectief 2019-2024) creates a virtual model (digital twin) of the Rijn-Maas delta. It integrates knowledge about processes in surface water on different space and time scales and will predict saltwater penetrating towards inland surface water and how nature-based solutions can mitigate these. In AC, solutions in the subsurface and fit-for-purpose water reuse are investigated and tools are developed for interaction between groundwater and surface water including salinity, which are complementary to SALTIsolutions.

The Dutch water authorities and drinking water companies have already initiated several circular water management and demo approaches in the so-called Water Factory (in Dutch "Waterfabriek") projects, with demonstration budgets of millions of euros, such as the Higher Sandy Soil region project WILP[26] (with DW company Vitens and WAs Vallei and Veluwe and Aa en Maas, both involved in AC), and New Hart[27] project (With WA NHNK and DW company PWN, in Amsterdam Region, both involved in AC). AC builds on and leans from these larger applied projects and ads on missing scientific components. The same holds for the Rijkswaterstaat-STOWA demonstration PILOT program on CEC compound removal (60 million Euro investment from 2021 on)[27]. Though CEC chemical and biotechnical removal is one of the most important issues to be considered in circular water approaches, the above mentioned program and other technology programs where AC partners already participate (WUR, UT, UVA, RHDHV, Witteveen and Bos, STOWA) will feed this knowledge into AC, motivated to only focus in AC on the risk assessment and in-situ biodegradation of polar CEC's in WP 3 and 4. Hence, though many projects have been or are running on water in the Delta in The Netherlands, AC has its own, original and unique niche, not repeating but complementing the projects mentioned, and addressing an urgent societal need for development of climate robust fresh water provision.

3.4 Consortium

Scientific consortium

Department	Expertise and complementarities
Environmental Technology (WUR) Prof dr. ir. Huub Rijnaarts (**number of publications**: 145, *), Dr. Nora Sutton (25), Dr. Jouke Dykstra (13), Dr. Shahab Shariat Torbaghan (18), Dr. Thomas Wagner (10), Katarzyna Kujawa (22).	Development of chemical water treatment technologies; Micropollutant risk assessment in water systems; Modelling of digital water networks under uncertainty. International water projects global south; Managing large (xx M€) multidisciplinary integrated RTD projects (*), last 20 years.
Soil Physics and Land Management (WUR) Prof dr. ir. Sjoerd van der Zee (90), Dr. Perry de Louw (43), Dr.ir. Ruud Bartholomeus (24)	Geohydrological modelling (soil-unsaturated zone-groundwater) to design ecological and productive land and water system
Landscape Functioning, Geo-computation and Hydrology (UU) Prof. dr. Marc Bierkens (183), Dr. Gualbert Oude Essink (47), Dr. Perry de Louw (43), Dr. Marios Karaoulis (12)	Groundwater modelling especially fresh and salt water interface dynamics, in response to human interventions and climate change
Department of Law/Utrecht Centre for Water, Oceans and Sustainability Law (UU) Dr. Herman Kasper Gilissen (8)	Legal aspects of innovations towards sustainability
Electrical Engineering (TU/e) Prof. dr. ir. Jeroen Voeten (44), Dr. Dip Goswami (63), Dr. Mircea Lazar (135), Prof. dr. Paul Van den Hof (187)	Smart Grid Design, Optimization and Control (Energy) Cross connecting this disciplinary field with Water resources management.
Environmental Policy Analysis (VU) Prof. Dave Huitema (65), Prof. Roy Brouwer (105)	Environmental economics, ecosystem services,, economic modeling, nature valuation. Adaptive governance, policy experiments, policy dynamics, policy entrepreneurship.
Freshwater and Marine Ecology (UvA) Prof. Annemarie van Wezel (75)	Chemical risk assessment, Environmental chemistry, Water quality in relation to Human and Ecological Health
Civil Engineering and Geoscience (TU/D) Prof. Nick van de Giesen (174), Dr. Edo Abraham (31)	Hydrology, water management, climate, networked water systems, water-energy nexus, numerical optimization, uncertainty modelling, optimal control.
Membrane Science & Technology (UT) Prof. Wiebe de Vos (68), Prof. Rob Lammertink (155)	Material Science to design membrane technologies for molecular water treatment
Deltares (DELT – TO2) Dr. Perry de Louw (43), Dr. Esther van Baaren (8), Hans van Duijne	Groundwater models, Salinization problems, water management, stakeholders management on knowledge development; management and organization large R&DI projects; *connecting to projects COASTAR, SALTISolutions*
HZ University of Applied Sciences (HZ) Dr. Hans Cappon (12), Dr. Teun Terpstra	Applications in water treatment: lab and pilot operations, (field) data acquisition and analysis, water governance and behavioral science related to practical application
Wageningen Environmental Research (WEnR – TO2) Dr. Koen Wetser (4), ir. Myrjam de Graaf	Integrated approaches and water governance in water preserving landscapes; *Connecting to projects "Zicht op elke druppel", KLIMAP*

* WELCOME (EU FW4, 2M€), CORONA (EU FW5, Biotech part 1M€), AQUATERRA-BASIN (EU FW6, 10M€ of 23M€), UPSOIL (EU FW7, 1M€), SOWACOR (KAUST-grant, Part Bioprocesses, 1M€ of 4M€), ENTIRE (NWO-UDW, 1.5M€), WATER NEXUS (NWO-STW Perspectief 2015, 6M€), UNLOCK (NWO Roadmap Large Infrastructure, 3.7M€ of 25M€)

User community

Technology-developing companies - Nijhuis Industries - NXFiltration - ICT Solutions	Technology providers for treatment of water on-demand, i.e. electrochemical technologies (Nijhuis), i.e. eager to develop ED, in addition to existing electro coagulation and RO approaches. Developing NF technologies (NXF), and design and user of local water grid services for water boards and drinking water companies (ICT Netherlands). (WPs 4,6,7).
Technology and consultancy companies - Witteveen & Bos - Royal Haskoning DHV - KnowH_2O	Consultancies supporting water authorities and drinking water companies with integrative circular water studies and water grid designs, including new landscaping and infrastructure, and implementation projects with contractors; inclusion of novel treatment and digital technologies herein (together with technology providers), and supporting governmental organizations in policy innovations (i.e. water reuse, brine and sludge management, and use of risk assessment methods; International marketing of Dutch approaches and technologies is more than 60% of the business. (WP 2,3,4,5,6,7).
Water user companies - Dow - Shell - Swinkels	Large industrial water producers and users; water as essential resource to produce i.e. securing to overcome scarcity; water produced as a resource to sustain local water scarce societies, i.e. greening the Dessert; water producer consumer, enforcing regional water approaches (WPs 2,3,4,5,6,7).
Drinking water companies - Vitens - Dunea - Oasen - Evides	Initiators of smart water grids together with water authorities, inclusions of the AquaConnect demonstrations. Extractions out of surface water and groundwater (including brackish water, and reinjection of brines) and enlarging dune infiltration capacities as drought overcoming resources and for mitigating salt water intrusions through the coastal subsurface. (WPs 2,3,4,5,6,7).
Water authorities - Rijn & IJssel - Vallei & Veluwe - Hoogheemraadschap Hollands Noorderkwartier - Scheldestromen - Aa en Maas - Drents-Overijsselse Delta	Innovations in water management, infrastructures and operations, including the design and creation of circular water systems by embedding new treatment chains and reuse of effluents, brackish water and storm water. Management of the surface water system in the region, including the transition towards improved water holding capacity by reducing discharge and increasing storage in subsurface and basins. Together with water companies initiators of smart water grids, the future management and operation of these and inclusions of the AquaConnect demonstrations in the case-studies (WPs 2,3,4,5,6,7).
Overarching organizations - STOWA - GlastuinbouwNL - Water Alliance - Netherlands Water Partnership	STOWA represents water board research in NL, GlastuinbouwNL, has great interests in local water grids, because the sector is threatened in business by fresh water shortage; Water Alliance is representing water technology companies in the NL to promote international outreach and marketing, and KnowH2O is an organization communicating and advising on water innovation issues (Espec WP7 and aspects of WP 2,3,4,5,6).
Research Institutes - KWR Water Research Institute - AMS institute	Applied knowledge institutes for circular urban systems including water provision (AMS); and helping the drinking and water board sector to adopt circular safe, secure and clean water provision through water treatment and in natural storage (KWR). (WPs 5,6,7).
Local governmental organisations - Municipality Terneuzen - Municipality Amsterdam	Water governance and policy innovations, including local infrastructures, local government (WPs 5 and 7)
Regional governmental organizations - Province of North-Brabant - Province of Zeeland - Province of South-Holland	Water governance and policy innovations, including national and provincial infrastructures, regional government, especially permitting ground water extractions and reinjections (WPs 2, 5, 7)
National governmental organizations - Ministery of Infrastructure and Water Management	Water governance and policy innovations, including national infrastructures; central government (WPs 5 and 7)

3.5 Outcomes related to scientific insights (Output)

Outcomes (OC) of AquaConnect (Table 3) are ultimately changes in practices in the Dutch and international Water Sector to ***ensure future fresh water provision in a drought-resistant water system***. These outcomes are related to the scientific insights following from the scientific objectives of AquaConnect (Table 2) and output (see Section 3.6.) i.e. better understanding on main aspects of nonconventional water based provision and buffering via interdisciplinary research integrating (geo-)engineering, environmental science, ecology, hydrology, water technology, social sciences (governance and economics), digital system control and optimization science (Fig. 3).

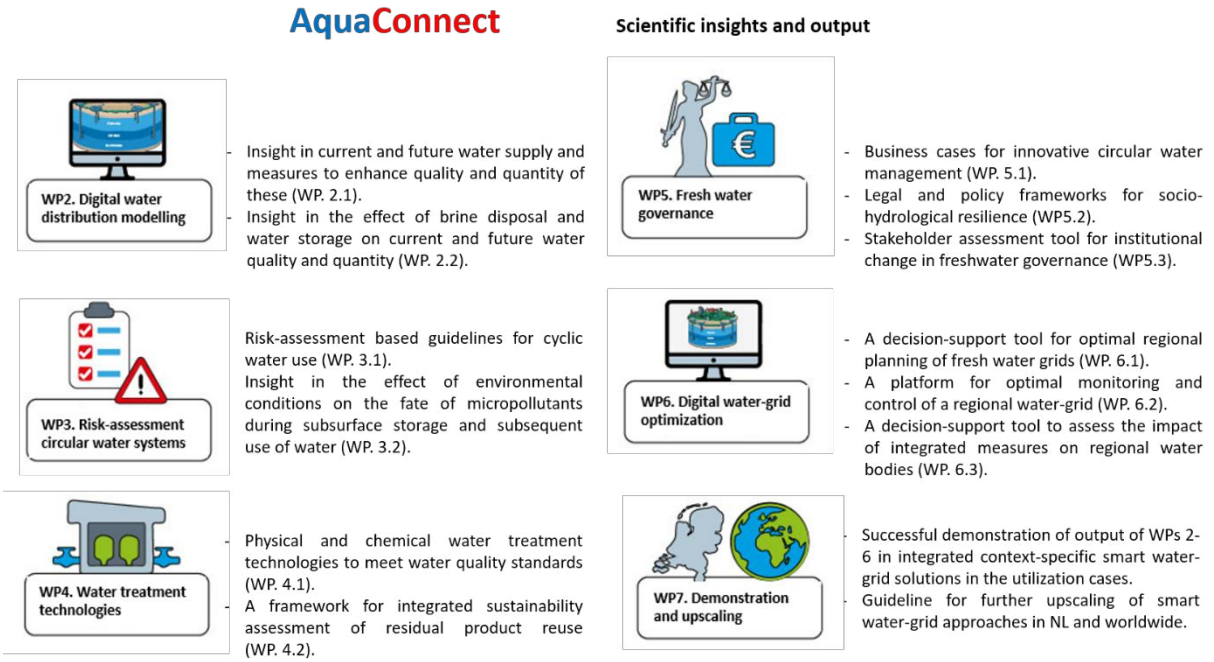

Figure 3. Scientific insights and output of AquaConnect workpackages.

Table 3. Outcomes of AquaConnect

Insights and output (Fig. 3)	**Outcome (OC)**
- WP5.1. - WP5.2 - WP5.3	**OC 1. Framework for institutional collaboration and interaction for circular water approaches.** Through AquaConnect, relevant stakeholders will optimize communicating their role in fresh water provision as developed and demonstrated in four case study regions. AquaConnect stakeholders will overcome current governance and economic barriers and enforce institutional roles in circular water management.
- WP2.1 - WP2.2 - WP3.1 - WP4.1 - WP5.1 - WP6.1 - WP6.3 - WP7	**OC 2. Explicit business cases enhancing economic and social drive to develop and implement nonconventional water based water grids.** The "profits" of the nonconventional water source based supply have become explicit: i) water grid controllers such as water authorities and water companies, or PPS collaborations, offer a secured provision and thus income to industry, agriculture, municipality and nature. Pressure on groundwater extractions is thus relieved. End users in industry, agriculture and nature pay for the smart grid water delivered but gain by secured conditions. Local communities gain in higher quality of the local environment, secured water provision and higher ecological value. Water technology providers develop their market in The Netherlands, and even more strongly internationally.

- WP2.2 - WP3.1 - WP3.2 - WP4.1 - WP4.2 - WP5.2	**OC 3. Regulatory base for use of nonconventional water resources, and sustainable management of brines and sludge.** By circular approaches intentionally using nonconventional water sources quality issues might appear, without adequate technological interventions. Contaminants can accumulate, and lead to adverse effects. For applications of effluents, brines and sludges to soil, surface and groundwater adequate standards are to be developed, which address the balance between the precautionary principle and natural cleaning capacities. New environmental legislation (e.g. Omgevingswet in NL, Water Reuse Regulation in EU) offer opportunities to implement the AquaConnect developments.
- WP3.1 - WP4.1 - WP5.1 - WP6.1 - WP6.2 - WP6.3	**OC 4. Nonconventional water sources are accepted and implemented as important part a drought-resistant water provision system.** Through AquaConnect, stakeholders are able to motivate that regionally organized smart grid measures (infrastructure, treatment technology, spatial planning) needed to be included in future fresh water provision, by quantitative and qualitative assessment of water demands including fit-for-purpose quality requirements, buffer capacities and use of nonconventional water sources.
- WP7	**OC 5. A portfolio for nonconventional water sources based smart water grids is showcased and ready to expand in the Dutch, European and global markets.** Through AquaConnect, a demonstration program is built and internationally disseminated including the following smart water grids: Zeeuws-Vlaanderen, South Holland including Port of Rotterdam, Smart Grid Higher Sandy Soil regions in adherence to the "WaterFabriek" (WaterFactory) program of WA, Smart Grid MRA including the renewed "New Heart/Wervershoof" waste water treatment facility and water redistribution for irrigating Amsterdam parks. Outreach twinning cases exchange knowledge with Vietnam (Circular water for Industry, industrial parks Ho Chi Minh City), Chili (Water Storage for agriculture), Qatar (Greening the Desert, potential expansion to Oman), and Bangladesh (Urban water for irrigation), and other future outreach potentials (Mediterranean areas via the EU Green Deal, with support of the NL Water Alliance, and future collaborations of the water authorities and drinking water companies running outreach program BLUEDEAL towards Africa and South East Asia.

3.6 Program structure

3.6.1 Overview program and projects/work packages

AquaConnect will consist of a project governance WP (1), five technical WPs (2,3,4,5, 6) that produce technologies and tools that will be implemented at different nodes in a smart water-grid and 1 WP (7) that focusses on demonstration, upscaling and outreach of AquaConnect smart water-grids in the case-study regions, NL and the world.

Work package 1 – Project governance. Within WP1, the program leader Prof. H. Rijnaarts is supported by a program manager in the daily management of the program. The program leader and program manager are responsible for integration of the research within the framework of AquaConnect, demonstration of the newly developed key-technologies in the four AquaConnect case-studies and dissemination of the outcomes of AquaConnect to other regions, in The Netherlands and abroad. (NOTE: there is another WP oriented on research on Governance of Water provision (WP5), not to be confused with WP1).

Work package 2 – Digital technologies for subsurface water distribution modelling. WP-leader: Prof. M. Bierkens

WP2.1. Regional high-resolution integrated groundwater-surface water modelling. Hyper-resolution and scalable coupled groundwater-surface water models will be developed that allow for calculation of current and future water supply, the effects of underground water storage and brine disposal, and the impact of local and regional application of chemical technologies to enhance water supply and water quality.

WP2.2. Management of fresh groundwater resources using data-model assimilation and model predictive control. Geophysical monitoring data are integrated with 3D numerical variable-density groundwater flow models to predict the status of fresh groundwater lenses in coastal zones and their reaction to future stresses. This provides tools for effective site-specific groundwater management, monitoring and control.

Work package 3 – Risk assessment of cyclic water systems that include nature-based treatment and storage. WP-leader: Dr. Nora Sutton

WP3.1. Risk assessment of re-use in cyclic water systems. Here we focus on the human and environmental risks of organic synthetic chemicals present in nonconventional water sources. Practical and science-based guidelines are developed for end-users in drinking water utilities, industries, and agriculture that have to decide on various options for water re-use. Also insights are developed into the effects of water re-use on the ecological system.

WP3.2. Improving prediction of micropollutants transformation product formation in groundwater systems. Key insights into the effect of the environmental conditions in groundwater on the fate and transformation of

micropollutants that threaten the water quality in closed water cycles is obtained that can be used for both conventional and new water sources.

Work package 4 – Chemical and physical technologies for fit-for-purpose water supply. WP-leader: Dr. J. Dykstra

WP4.1. Fit-for-purpose water treatment including brine-management. A combination of novel nanofiltration- and electrodialysis membranes will be developed that allow the tailor-made treatment of diverse water-streams for the removal of specific contaminants, also allowing to make brines compatible for further treatment or disposal.

WP4.2. Managing and engineering quality effects of effluents, brines and sludges for application in soil and groundwater. A framework for sustainability assessment of the effect of infiltrating treated effluents and sludges to soils to enhance crop production, and brines to saline aquifers, to minimize environmental impact will be developed by modelling and testing different environmental subsurface compartments.

Work package 5 – Freshwater provision governance. WP-leader: Prof. D. Huitema

5.1. Socio-economic analysis of sustainable circular water governance systems. A hydro-economic model will be developed that assesses the economic benefits associated with innovative circular water management.

5.2. Assessment of legal and policy issues to foster regional socio-hydrological resilience. Local, regional, national and supranational legal and policy frameworks that enable socio-hydrological resilience will be analyzed and evaluated. Based on in-depth case study research and comparative analysis transferrable good practices will be identified.

5.3. Science-policy interactions, stakeholder involvement and upscaling. Design of an integrated assessment tool for stakeholders that allows an institutional change in fresh water governance.

Work package 6 – The digital smart water-grid. WP-leader: Prof. H. Rijnaarts

WP6.1. Robust optimization of future smart water grids at scale: harnessing heterogeneity of supply and demand through centralized and decentralized decision systems. A decision support tool will be developed for regional planning by analyzing opportunities for the distributed production, storage and transport of water to different users through analysis of users' consumption patterns, water quality needs and possible supply sources.

WP6.2. Real-time monitoring and model predictive control of smart water-grids. Model predictive control algorithms and multi-core computational platforms will be used to develop a fast and integrated local water embedded model predictive control solution that controls water distribution systems based on current and future water demands.

WP6.3. Region redesign towards improved fresh water availability. Development of a fast-calculating tool that assesses the impact of a set of integrated measures for improved fresh water availability on regional subsurface and surface water bodies and water users.

Work package 7 – Demonstration and (inter)national application. WP-leader: Prof. H. Rijnaarts, supported for

- integration and national upscaling by Paul Roeleveld (RHDHV) and Arjen van Nieuwenhuijzen (WI & Bos), and
- international outreach, by H. van Duijne (Deltares) and Dr. Katarzyna Kujawa (WUR)

The postdocs and applied knowledge institute researchers ensure inclusion of scientific findings of WPs 2, 3, 4, 5 and 6 into demonstration and application in direct interaction with case-related stakeholders in Zeeuws-Vlaanderen, MRA, Zuid-Holland and the Higher Sandy Soils. AquaConnect PhDs will be linked to the (ongoing and planned) long-term field scale pilots and demonstrations, which are executed by the knowledge institutes within the framework of other research programs, such as COASTAR and Lumbricus (section 3.3), this way strengthening the scientific basis for the solutions applied. Demonstration in the case-studies will lead to a toolbox of key technologies which can be implemented in a smart water-grid that can also be used in other regions in The Netherlands, and worldwide.

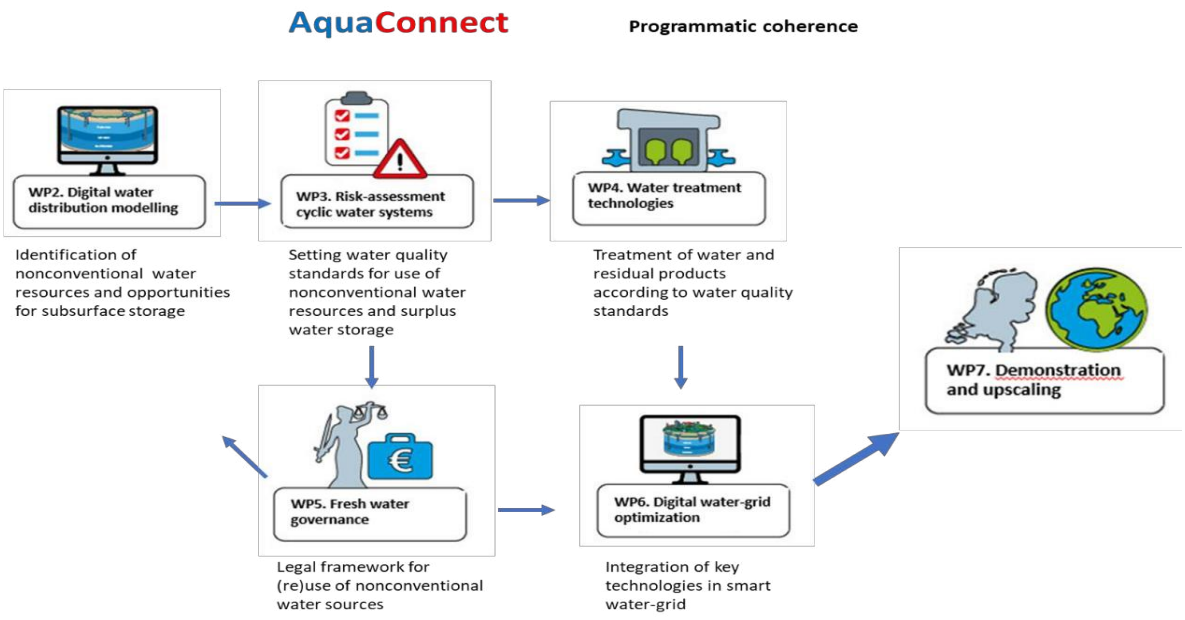

Figure 4. Program work package coherence.

3.6.2 Added programmatic value

The integration of scientific insights from diverse fields, i.e natural and anthropogenic water systems modelling, water treatment and water governance, is key to creating regional climate-robust fresh water-grids that ensure future fresh water supply in water-scarce areas. To facilitate the integration and implementation of key technological solutions, AquaConnect will integrate these disciplines within one project, with the aim to demonstrate the integrated regional smart water-grids in the four case-study areas in The Netherlands (WP.7). The definition of the scientific and technical challenges for developing smart water-grids during the co-design phase (section 3.2) has been instrumental for the identification of the scientific research questions within AquaConnect and forms the basis for the synergy within the scientific workpackages (Fig. 4). In WP2 of AquaConnect, key digital tools will be developed that will be embedded within currently existing digital instruments for decision-support in water management in The Netherlands, such as The Netherlands Hydrological Instrument (NHI). These tools allow the identification of new water resources and the impact of extracting these from the subsurface (WP2.1 &2.2). Various digital, chemical and biological risk-assessment methods will be developed (WPs 3.1, 3.2 & 4.2) to identify potential chemical and physical risks of using new water resources in a circular water approach, which will also form input for WPs 2.1 & 2.2 in the identification of suitable new water resources. In addition, the outcomes of these risk-assessments (WPs 3.1, 3.2 & 4.2) will provide a target group of harmful chemical pollutants in circular water systems, either due to their toxicity or persistency, that need to be removed by fit-for-purpose treatment (WP4.1). Similarly, harmful chemical pollutants in brines and sludges, whose production is inevitable with fit-for-purpose treatment, will be identified, which allows their targeted removal to make brines environmentally compatible and dischargeable (WP4.1 & 4.2). Furthermore, the risk-assessment (WPs 3.1, 3.2 & 4.2) is tightly connecting the different current legal constrictions for water reuse and water discharge, and improved insights in chemical and physical risks within cyclic water systems provides the scientific knowledge that is required to evoke a paradigm-shift in water governance, which is reluctant to reuse and storage of used and treated water sources (WP5). These new water sources require optimal distribution among the various users (WP6.1), taking into account already existing infrastructure, existing and in AC developed fit-for-purpose treatment technologies (WP4.1), socio-economic and legislative boundary conditions (WP5), ultimately leading to a design of a regional water system that ensures that water users will receive this new water sources, without profound negative effects of water-extraction on the environment (WPs 6.3 & 3.1). This water-grid design requires real-time monitoring for optimal operation of the water grid (WP6.2). Ultimately, project governance stimulating the integration of all scientific results (WP1 and WP7 by input of the utilization perspective of the four selected delta regions) needs to result in tangible technological solutions that will be demonstrated in the different case-studies in The Netherlands, and scaled up nationally and abroad (WP7).

3.7 Risk management and contingency plan

Experience from participating in earlier large NWO research-consortia shows that as a result of the separation of a large project in individual financially independent projects at the separate universities, the integration between WPs and the integration of the scientific outcomes in demonstration projects cannot be enforced and the WPs become independent. To prevent this, AquaConnect will be one large project with different work packages, with Prof. dr. ir. Huub Rijnaarts of the Department of Environmental Technology of Wageningen University in the lead, supported by an 0.4 fte program manager. The integrative collaboration will be supported by the AquaConnect recruitment challenge and integrative design workshops through-out the program (3.8, points 2 and 4). To support the integration of the full program and to mitigate risks when implementing a contingency plan in the connection between the scientific WPs and demonstration projects, a Scientific Committee (SC), an End User Committee (EUC) and an Advisory Board (AB) will be part of the program-management structure (section 5.1). These committees will address the following risks:

- The risk that scientific excellence will be affected due to the requirement that scientific challenges need to be connected to the demonstration projects. The SC will ensure scientific excellence within the different WPs.
- The risk that the integration of the scientific findings into application can only be obtained when there is attention for scalability, cohesion and integration of the challenges in the demonstration project.
- The risk of limited cooperation between PhDs and Post Docs and a lack of integration of their work into the demonstration projects.

The AB will oversee to the overall management of the program, the integration of the results obtained in different WPs, program communication, risk mitigation and the connection of AC to other research programs, such as SALTIsolutions, KLIMAP and COASTAR, and the international outreach. The translation of the scientific challenges and its connection with the demonstration projects is implemented along the use of the TRLs (Technology Readiness Levels); the connection of all WPs and the demonstration projects is supported by the End User Committee according to objectives and design criteria set during workshops. The project leaders of the demonstration projects are employed by the research institutes, have management experience and are capable of leading projects and taking over management tasks from others if required. These program managers also participate in other research programs, such as COASTAR and KLIMAP, allowing AC to connect to already existing demonstration projects. During the first half year of the program, several workshops are planned to determine the more detailed progress objectives, milestones and criteria for each WP and demonstration projects with the end users and with the scientific program community (section

5.1). These criteria will be used as indicators during progress reporting of WPs and demonstration projects. During the workshops, the milestones, risks and mitigation strategy will be discussed, agreed and written down in a project management document (WP1). After the workshops during the first half year of the program, we plan two meetings per year with end users and stakeholders (see 3.8 point 4) to discuss integrative activities, potential risks, mitigation measures to guarantee coherence, program ethics and shared responsibilities, which is important for the success of AC.

3.8 Utilisation plan

The outcomes (OCs) of AquaConnect (section 3.5) based on the scientific insights (Fig. 3) and deliverables (Fig.2, A-F) obtained by the different scientific workpackages (WPs, Fig. 1, 2)) will be utilized by all participating organizations connected within AquaConnect (section 1.4, table 4) to successfully design and implement new grids for regional fresh water provision based on alternative water resources**.** In the process to adequately bring knew knowledge (SIs and deliverables) to implementation (realization of the OCs) we adopt a detailed **Utilization Strategy**, with the following steps.

1. **Assessing knowledge needs and maximizing utilization potential in the proposal phase**. During the formation of the AquaConnect program, the desired outcomes and associated generation of knowledge (SIs) in WP 2-6 for tools and technologies, case studies and outreach potential (WP7) have been defined by several online scientist-stakeholder workshops, with stakeholders on a national platform (STOWA, Ministry I&W, Water Alliance) and on the level of the four case studies. This way, the AquaConnect proposal has been established using the Theory of Change and Route-to-Impact concepts of the NWO Perspective program. By doing so, stakeholders already defined their concept of “Smart Water Grids based on use of alternative water resources” to be designed and subsequently implemented in their region, and the (inter)national upscaling potential of the approach.
2. **Initiating Route to Impact and implementation of results at the start of AC.** Upon approval and start of the AquaConnect program, we will organize two kick-start events: i) **knowledge to impact workshop** for AquaConnect case-study stakeholders and all supervising scientific supervisors of future PhD’s and postdocs to further detail the research questions in relation to the design of local water provision grids using alternative resources (in which STOWA, RHDHV and WI&BO have offered to take lead, together with the coordination team), and ii) an **AquaConnect Recruitment Challenge** for all PhD and postdoc positions where two candidates will be proposed by the supervising PI’s to take part in the challenge. Best candidates will be selected on i) the ability to perform the specific scientific research, ii) creative, integrative and interactive skills, iii) ability and interest in contributing to sustaining stakeholder interaction during the project. Hence a **PhD and postdoc community with high science and integrative and stakeholder communication abilities** will be established. This group will be complemented with the TO2 and HZ applied researchers and managers, with integrative tasks for the case studies and developing AquaConnects’ main deliverable, the design and demo of smart water grids based on alternative water resources in four case study regions.
3. Following the concepts of the consortium agreement set up in interaction with NWO, most of the AquaConnect **knowledge generated will be fully open to all consortium partners**. For **selected technologies**, i.e. those of WP4.1 (ED/NF technology), and WP6.2 (Smart Grid Control), a **limited knowledge and IP sharing regime** will be applied to those co-financing and knowledge developing partners involved. This is to protect future market positions of involved partners in these WP’s. For national utilization of open and restricted technologies, contract conditions as put forward AquaConnect participating organizations will be needed to be taken in to account, in completing the Consortium Agreement and undersigning by all parties, which is mandatory in the starting phase of AquaConnect, when granted.
4. **The creation and integration of knowledge towards in practice implementable smart water grids during implementation of AC.** During the project implementation phase, especially the first 2 years in creating a joined approach, we organize continued **Workshops on Knowledge to Impact** with PhDs/postdocs and supervisors and stakeholders. Moreover, in many **bilateral WP based collaborations**, stakeholders will give input through approximately 70% of their in kind contributions (which is 1 M€ in kind input divided over de 4 case studies) to the different parts of AC, linking the project to practice. In addition, the university partners will connect their education programs to AC, i.e. at minimum **50 BSc and MSc students** will conduct their thesis and internship graduation parts, in collaboration with co-financing stakeholders and PhDs and postdocs delivering two things: i) **direct practice-linked research**, and ii) offering **Human Capital to companies and governments,** in addition to PD and PhDs, having AquaConnect built knowledge. Moreover, all research results of WP2,3,4,5, and 6 are channeled to application of technologies (chemical, digital) and governance tools in the four case studies in designing and demonstrating smart water grids using alternative water resources. This will be done by a yearly **smart grid design workshop** per case study, with all involved.

5. **Upscaling in the The Netherlands and global outreach.** The four demonstrated smart water grids in the four case study regions will be integrated to generic Smart Water Grid approaches for different situations under control of WP 7, and be brought to generic concepts that can be made scalable for outreach in The Netherlands and internationally. In WP 7, the stakeholders will heavily contribute, spending about 400 k€ (30% of their in kind) contribution to upscaling, knowledge dissemination and market transfer. Though all have a role in this, organizations like STOWA, Water Alliance, AMS, and the TO2 institutes and international consultants take lead in this, while the universities will trigger their scientific networks for supporting spin off projects and innovations also abroad, i.e., Vietnam, Bangladesh, Canada, Qatar, Oman and Chili. The water authorities and drinking water companies will include their BlueDeal Program, including the smart water grid approach into their offerings in water provision and sanitation to developing and emerging economies around the globe.

Tabel 4. AquaConnect outcomes (related to SIs and deliverable of WPs) taken up by stakeholders and realizing impact

	OC related to SIs (WP)	**Stakeholders receiving and co-creating knowledge and further translating this towards implementation of alternative water grids in practice**
1	**Framework for Institutional collaboration and interaction for circular water (5,7)**	National authorities (Ministry of Infrastructure & Environment), overarching institutions (Port of Rotterdam, GlastuinbouwNL, STOWA), provinces (Zeeland, South-Holland), municipalities (Terneuzen, Amsterdam), water authorities (Rijn en Ijssel, Vallei & Veluwe, Hoogheemraadschap Hollands Noorderkwartier, Vechtstromen).
2	**Business cases, economic and social drive for alternative water grids (3,5,6,7)**	Drinking water companies (Vitens, Oasen, Dunea, Evides, Brabant Water). Former water users within the smart water grid (Dow, Shell, Port of Rotterdam); Technology-developers (Nijhuis Industries, NXFiltration, Drainblock, ICT Solutions) in collaboration with consultancy-companies (RHDHV, Witteveen & Bos) and research institutes (Deltares, KWR, WEnR, HZ, AMS).
3	**Regulatory base for use of nonconventional water resources, brines and sludges (2,3,4,5)**	National, regional and local authorities (Ministries, provinces and municipalities) and water authorities will adopt new risk-based legislation concerning circular water use and brine- and sludge production in a regional water-grid. Water-treatment technology developers will provide the technologies required to meet the quality-standards for water, brine and sludge reuse in water-grids.
4	**Alternative water grids shown and accepted as important part of drought-resistant water systems (2,3,4,5,6,7)**	OCs 1-3 and the corresponding utilization plans will connect all participating organizations in AquaConnect with the aim to develop and demonstrate the physical and digital water regional water-grid, in which each organization is aware of their role and responsibilities.
5	**Showcase portfolio for nonconventional water grids expanded in The Netherlands, European and Global markets (7).**	Technology-providers (Nijhuis, NXFiltration, ICT) overarching institutions (Water Alliance, AMS, STOWA, NWP) and consultancies (RHDHV, WI&BO, KnowH_2O); Water users (Shell, Dow); Water authorities and drinking water companies, nationally and internationally (BLUEDEAL). Universities (WUR, UU, UvA, VU, TU/D, TU/E, UT) and research institutes Deltares, KWR, WEnR through existing collaborations nationally and abroad.

Workpackage	**Research groups applying**	**Involved users**
1. Project Governance	**Wageningen University**, Environmental Technology (Prof. H. Rijnaarts)	Witteveen&Bos Royal Haskoning DHV ICT Netherlands B.V. NXFiltration Nijhuis Industries Dow Benelux Shell Global Solutions GlastuinbouwNL Swinkel Family Brewers Port of Rotterdam North Sea Port KWR Water Research KnowH_2O Water Alliance AMS NWP Province of Brabant Province of Zeeland Province South-Holland Municipality Terneuzen Municipality Amsterdam Ministery of I&W Dutch Embassy Chile Dunea Vitens Oasen Brabant Water Evides Industriewater WA Scheldestromen WA Vechtstromen WA HHNK WA Rijn & Ijssel WA Aa en Maas WA Vallei en Veluwe STOWA
2.1. Regional high-resolution integrated groundwater-surface water modelling.	**Utrecht University**, Landscape Functioning, Geo-computation and Hydrology (Prof. M. Bierkens)	
2.2. Management of fresh groundwater resources using data-model assimilation and model predictive control.	**Utrecht University**, Landscape Functioning, Geo-computation and Hydrology (Prof. M. Bierkens)	
3.1. Risk-assessment of re-use in cyclic water systems	**University of Amsterdam**, Institute for Biodiversity and Ecosystem Dynamics (Prof. A. van Wezel) **Wageningen University**, Environmental Technology (Dr. N. Sutton)	
3.2. Improving prediction of micropollutant transformation product formation in groundwater systems	**Wageningen University**, Environmental Technology (Dr. N. Sutton) **University of Amsterdam**, Institute for Biodiversity and Ecosystem Dynamics (Prof. A. van Wezel)	
4.1. Fit-for-purpose water treatment including brine management	**University of Twente**, Membrane Science & Technology (Prof. W. de Vos) **Wageningen University**, Environmental Technology (Dr. J. Dykstra)	
4.2. Managing and engineering quality effects of effluents, brines and sludges for application in soil and groundwater	**Wageningen University** - Soil Physics and Land Management (Prof. S. van der Zee) - Environmental Technology (Prof. H. Rijnaarts)	
5.1. Socio-economic analysis of circular water governance	**Vrije Universiteit**. Environmental Policy Analysis (Prof. D. Huitema) **Utrecht University**, Department of Law/Utrecht Centre for Water, Oceans and Sustainability Law (Dr. H.K. Gilissen)	
5.2. Assessment of legal and policy issues to foster regional socio-hydrological resilience	**Utrecht University**, Department of Law/Utrecht Centre for Water, Oceans and Sustainability Law (Dr. H.K. Gilissen) **Vrije Universiteit**, Environmental Policy Analysis (Prof. D. Huitema)	
5.3. Science-policy interaction, stakeholder involvement and upscaling	**Vrije Universiteit**, Environmental Policy Analysis (Prof. D. Huitema)	
6.1. Integrated water system, infrastructure and technology screening	**Technical University Delft**, Water Management (Dr. E. Abraham) **Wageningen University**, Environmental Technology (Dr. S. Shariat Torbaghan)	
6.2. Real-time monitoring and model predictive control of smart water-grids	**Eindhoven University of Technology**, Electrical Engineering (Prof. J. Voeten)	
6.3. Region redesign towards improved fresh water availability	**Wageningen University**, Soil Physics and Land Management (Prof. S. van der Zee)	
7. Case-study demonstration and (inter)national outreach	Deltares, Wageningen Environmental Research, HZ University of Applied Sciences, WUR	

Table 1. Schematic overview of the program.

4 Financial planning

4.1 Overview of the program budget

AquaConnect is executed as one large project containing a Project Governance work package, 5 scientific work packages and a work package dedicated to technology demonstration and (inter)national outreach. Subdivision of the program in financially independent projects is avoided to prevent project segregation and stimulate integration of all scientific results in integrated solutions for freshwater provision in delta areas (section 3.7). The Department of Environmental Technology (WUR) is in charge of arranging the project finances and IP-arrangements, for which an IP-agreement was crafted in consultation with NWO (see Appendix).

Budget	**Budget universities**	**Co-funding**	
WP1. Project Governance**	**Total:** € 170.141	**In-cash**	**In-kind**
WP2. Digital technologies to identify new groundwater resources and determine the impact of its extraction. **WP3.** Risk-assessment of cyclic water systems that include nature-based treatment and storage **WP4.** Chemical and physical technologies for fit-for-purpose water, brine and sludge supply **WP5.** Freshwater provision governance **WP6. The digital smart water-grid** **WP7.** Case-study demonstration and (inter)national outreach	**Personnel positions:** - 13 PhDs: € 3.108.326 (48 months) - 1 Postdoc: € 235.705 (36 months) - 3 Postdocs: € 348.288 (18 months) **Consumables:** *€580.000* **Travel abroad:** *€ 114.000* **Universities of Applied Sciences:** HZ University of Applied Sciences: € 200.070 (2106 hours) **TO2 Institutes:** Deltares: € 150.005 (1579 hours) Wageningen Environmental Research: € 150.005 (1579 hours)	Witteveen&Bos, € 30.000,- ICT Netherlands B.V. € 20.000,- WA Rijn & Ijssel € 25.000, - Province of Brabant € 20.000,- KWR Water Research € 25.000,- Royal Haskoning DHV € 30.000,- Shell Global Solutions € 100.000,- AMS € 75.000,- Municipality Terneuzen € 40.000,- WA Vechtstromen € 20.000,- Vitens € 90.000,- North Sea Port € 10.000,- WA HHNK € 40.000,- STOWA € 100.000,- Province of Zeeland € 100.000,- WA Aa en Maas € 20.000,- Oasen € 50.000,- WA Vallei en Veluwe € 20.000,- Brabant Water € 25.000,- Dow € 60.000,- Nijhuis Industries € 40.000,- Evides Industriewater € 60.000,- Province South-Holland € 75.000,- Municipality Amsterdam € 50.000,- Dutch Embassy Chile € 8750,- NXFiltration € 25.000,- Dunea € 100.000,- WA Scheldestromen € 60.000,- Ministery of I&W € 100.000,-	Witteveen&Bos, € 25.132,- ICT Netherlands B.V. € 20.000,- Port of Rotterdam € 8240 WA Rijn & Ijssel € 25.000, - GlastuinbouwNL € 24.750 Swinkel Family Brewers € 6592 Water Alliance € 25.890 Province of Brabant € 20.000,- KWR Water Research € 75.000,- Royal Haskoning DHV € 50.000,- Shell Global Solutions € 6180,- KnowH_2O € 20.480 AMS € 14.832,- Municipality Terneuzen € 16800,- WA Vechtstromen € 10.300,- Vitens € 93.137,- North Sea Port € 9940,- WA HHNK € 20.000,- STOWA € 9600,- Province of Zeeland € 16.000,- WA Aa en Maas € 9340,- Oasen € 100.000,- WA Vallei en Veluwe € 10.000,- Brabant Water € 6592,- Dow € 40.115,- Nijhuis Industries € 9940,- Evides Industriewater € 39.895,- NXFiltration € 90.950,- Dunea € 120.510,- WA Scheldestromen € 25.000,-

** The NWO budget for the Governance project is limited to 5% of the funding requested from NWO for the entire program.

5 Description of the projects/WPs in the program

5.1 Project Governance

WP. 1. Project Governance
Project leader: Prof. H. Rijnaarts (WUR) **User committee:** The project leaders of the individual projects/WP and user delegations constitute the user committee of this project.

5.1.1 Program management

The AquaConnect program is led by program leader Prof. H. Rijnaarts, who is supported by a program advisor from Deltares (Hans van Duijne) and program manager (0.4 FTE). The program management will be responsible for the overall management of the AquaConnect program in close cooperation with the AquaConnect Management & Integration Team (AMIT) (Fig. 4). The AMIT is the operational management team of the research and implementation program, which will closely monitor cooperation between different parties multi discipline scientist, water provision organizations, technology providers and governmental and industrial end users, involved in AquaConnect. In addition, the AMIT will oversee all scientific development activities in the WPs 2, 3, 4, 5 and 6 and actively steer towards their application in the case-study regions in WP. 7 .

The composition and meetings of the ACMT is as follows (Fig. 5):

- The program leader (PL): Prof. dr. ir. H.H.M. Rijnaarts, program advisor and program manager
- The scientific project leaders from the five scientific WP's, who are assisted by appointed postdocs
- The demonstration project leaders from the four case-study regions, who are connected to the research institutes (HZ, KWR, AMS, Deltares) with support of the consultancy companies WI &BO and RH DHV.

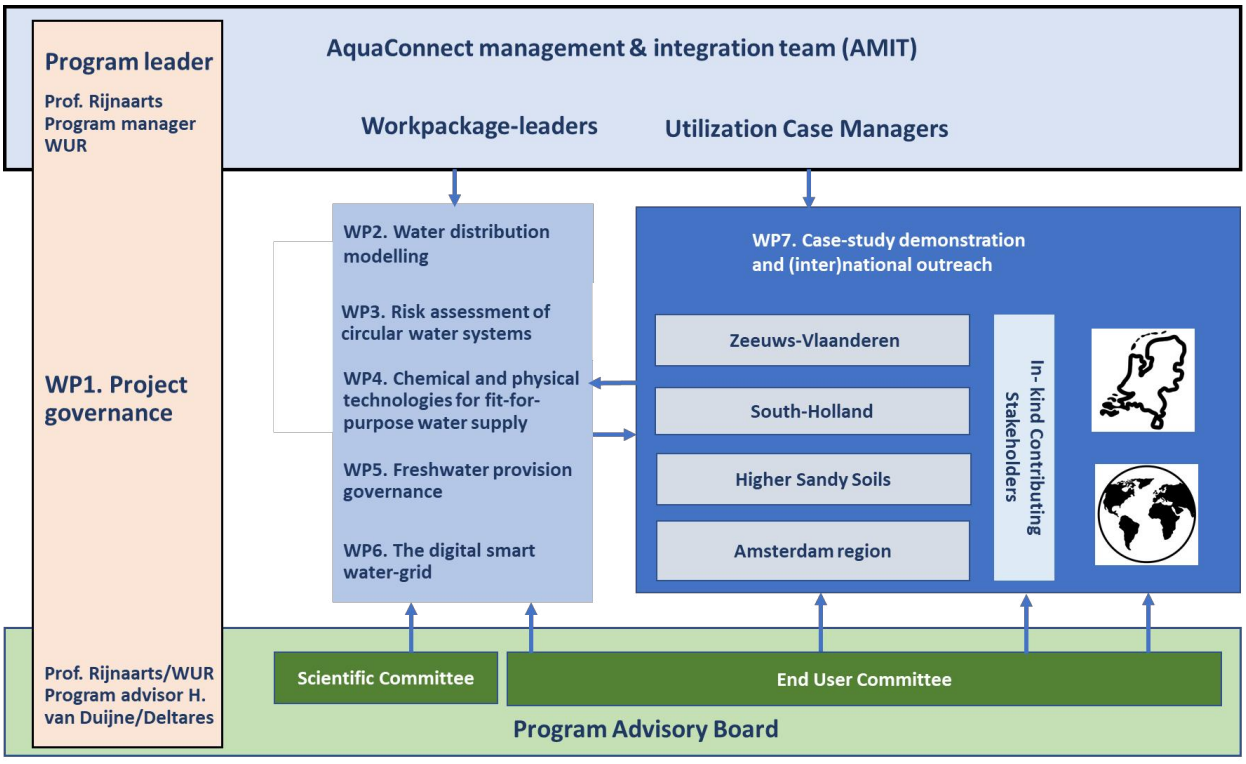

Figure 5. Management structure of AquaConnect

Besides the daily management (AMIT), three additional committees will be established:

- The scientific committee (SC), with representatives from the universities involved in WPs 2,3, 4, 5 and 6 and (optional) international science groups, who will guard scientific excellence of the scientific research performed.
- The demonstration project end user committee (EUC), with representatives from the four case-study areas in The Netherlands, who will ensure the applicability of the outcomes of the scientific research within the different case-study regions in The Netherlands.

- The advisory board (AB), which consists of the representatives of the EUC and SC, the PL and the PM, who will oversee progress of the individual scientific and demonstration projects and stimulate knowledge dissemination and technology integration.

5.1.2 Activity planning

Communication. The communication strategy of AquaConnect is aimed at four target audiences: Internal communication with consortium partners, communication with case related stakeholders, communication with potential national and international outreach stakeholders and communication with a wider audience. For each of these groups several communication activities are planned (see also 3.8, points 2 and 4):
Internal Communication. The objective of the internal communication is to achieve active involvement and good collaboration within the consortium by informing, sharing and discussing planning, activities and results. The activities include: i) Bimonthly email updates, ii) Discussion board, polls and file share at a Microsoft Teams group to involve the entire consortium, iii) Workshops (see program activities), iv) Internal interactive website for knowledge sharing
Stakeholders communication. The objective of the case related stakeholders communication is to generate awareness among the stakeholders about AquaConnect and to understand the visions and wishes of the different stakeholders. Activities include: i) Quarterly update mail, ii) Launch event per case study to inform and understand perspectives of stakeholders, iii) Final event per case study to discuss results and future plans.
Outreach communication activities aims at knowledge development and transfer between the AquaConnect case studies and the national and international outreach projects. Activities planned are: i) Workshops with the outreach projects to connect outreach projects to scientific research of AquaConnect (organized and hosted by the outreach team (WP7)); ii) Annual dialogue sessions with AquaConnect case study and international outreach twinning projects. iii) Interactions via limited access website for interactive extended partners; iv) in house workshops of related partners (NWO-TTW, Min I and W, Min Economic Affairs, STOWA, Water Alliance etc.).
Wider audience communication activities to inform and transfer knowledge. Activities planned: i) Website with program overview, scientific outputs, case related activities and a bimonthly news item, ii) Kick Off, Mid-term and Final conference; iii) Developing/implementing a media strategy to popular scientific journals (H2O), news on national television and newspapers, partner newsletters, and selected social media; iv) Orange Knowledge Program of ministry of economic affairs and Dutch Embassies and RVO and international workshops organized by BLUEDEAL program of water authorities and drinking water companies; v) Scientific conferences in the various disciplinary areas of the participating scientific partners.

Monitoring & Evaluation. The monitoring will be done at different levels and for different stakeholder groups. We can identify the governmental level, the end user level, the application level, the technology providers level, the scientific excellence level. Each of these levels has its own priorities. We need to come to an understanding how to monitor for which group. A workshop at the start of the program is planned to come to an agreement and set the criteria, the milestones, and monitoring schedule. The first end user meeting is used to set up a set of criteria for the monitoring of the project by the stakeholders from the government, end users, science, technology providers. This meeting takes place before the PhD's start their research, to be able to give additional information and boundary conditions to the PhD's. This means that we probably cannot satisfy all partners equally. So, there must be a hierarchy in the design of monitoring elements, which is:

1. scientific excellence in publications (ca 50-60 publications are foreseen in open access journals and PhD theses);
2. application of the research in the demonstration projects (four demo's foreseen in the utilization regions);
3. integration readiness of the technologies (chemical and digital technologies brought from 2-4 to 5-6 TRL level);
4. technology application in the demonstration projects (four demo's foreseen in the utilization regions);
5. potential success of the demonstration projects in The Netherlands (interviewing four cases stakeholder);
6. applicability of scientific results and its input to demonstration projects abroad (by consultancies and Water Alliance)

For each level, specific criteria (KPI's) will be set during the first-years' workshops sessions. After setting these criteria, we need to evaluate during the program how this monitoring process evolves and possibly adapt it. The financial monitoring is done between the main recipient (WUR) and TTW. The AquaConnect program opts for a centrally managed financial system. Therefore, the WUR manages the financial distribution to the different partners.

Program activities. The PL's of the scientific WP's the PL's of the cases will define the criteria, impacts, risks and actions in the demonstration projects in order to enable direct implementation of results in The Netherlands and abroad. The partner universities will arrange that the PhD students and postdocs will work together at the same location at regular intervals. PhD students will not only spend time at their 'home' university, but also spend part of their time at the applied research institutes and the end user premises (with permissions). The activities to connect the scientific WP's and demonstration projects are: i) Workshop(s) organized in collaboration with STOWA, the (union of) water

authorities, Deltares and Stibbe to map what is required, besides research and innovation, in order to put innovations into practice: define criteria for the design, assessment of benefits/impacts, monitoring, risks and pre-design for potential demonstration projects; ii) Workshop session(s) with the end users to evaluate, adapt and select from the pre-designs for the potential demonstration projects; iii) Brainstorm session with the scientific groups to search for the connection with the potential demonstration projects; iv) Workshop with the technology providers to see where they can fit in their technology in the projects and discuss additional research to their technology; v) Workshops with the scientific WP's and WP on demonstration projects to design a monitoring, risk and adaptation program; vi) A closing workshop to close the loop and determine a demonstration project for each region; vii) A monitoring session each year to evaluate the (intermediate) results and adapt.

The general activities are for all the participants in the AquaConnect program: A Kickoff General Assembly at the start of the program; An annual General Assembly; Workgroup meetings for each work package; A conference at the start, mid-term and end of the program.

5.1.3 IP position and strategy

AquaConnect will adopt an IP-strategy in which the project management is responsible for drafting the IP arrangements (NWO 'Eigen IE&P afspraken'). A concept-description of the IP-arrangements is approved by NWO. The AquaConnect IP construction consists of 2 IP-domains: an open domain and an IP-restricted domain. It is foreseen that 95% of the AquaConnect output will fall in the open IP-domain. To protect IP-sensitive technologies of technology-developers, a restricted IP-domain is crafted, which will be needed for at least WP 4.1 (Chemical treatment technologies) and 6.2. (Digital Smart Grid Control).

5.1.4 Overview requested budget

	I. Program management*	II. Program activities	III. Collaboration researchers and users	IV. Implementation	V. Monitoring and evaluation
Requested budget	€ 137.141	€ 7.000	€ 8.000	€ 10.000	€ 5.000
Description	0.4 FTE program manager + benchfee	Workshops. Many workshops are provided by in-kind support users	Field trips to 4 utilization regions *2.000 = € 8000	Update utilisation plan € 5.000 Outreach € 5.000	Midterm € 5.000

5.2 Research work packages

5.2.1 Work package 2: Digital technologies to identify new groundwater resources and determine the impact of its extraction

WP 2.1. Regional high-resolution integrated groundwater-surface water modelling

Project leader: Prof. Dr. M.F.P. Bierkens, Utrecht University
Co-applicant(s): Dr. G.H.P. Oude Essink, Dr. P. de Louw, Deltares
Requested research positions: 1 PhD, 1 Postdoc; **Duration of project**: 4.5 years

Scientific description of the WP

We develop case study-specific hyper-resolution and scalable integrated groundwater-surface water models (IGSMs)[1,2] that allow for the calculation of current and future water supply (including water quality/salinity), water storage possibilities, the effects of human water use, and the impacts of local and regional applications of chemical and nature-based technologies to enhance water supply at three case studies: Zuid-Holland, Zeeuws-Vlaanderen and a Sandy Soils subregion. These models are nested in the coarser-scale National Hydrological Model (LHM fresh-salt[3]) to be consistent with national scenarios and are built on schematizations of regional fresh-salt groundwater models (Zuid-Holland, Zeeuws-Vlaanderen). The models simulate surface water and groundwater flow for individual pilots as well as the effects of large-scale drivers (e.g., climate change) and many regional local interventions. Specific questions are answered, such as the effects of brackish groundwater extraction and brine injection (Zuid-Holland) and maximization of aquifer storage and recovery (Zeeuws-Vlaanderen and Sandy Soils).

Scientific challenge

Technical challenge: 1) models need to be able to seamlessly scale between regional (100m resolution) to local scale (5-10m resolution); 2) hyper-resolution scalable IGSMs are subject to large computation times. Scientific challenge: 3) regional-scale combined climate and socio-economic future scenarios are not yet available; 4) the fate of brine when injected into a heterogenous underground and the effects of brackish groundwater extractions are not well-known and not represented in current models; 5) model and hydrogeological parameters need to be up- and downscaled seamlessly.

Contribution to other work packages

The IGSMs take a central role in AquaConnect as they are used as a platform to test regional effectiveness and robustness of various water extraction, storage, recycling and redistribution strategies (tasks 8/9 below) developed in WP4. The IGSMs are subsidiary to the case studies (WP7) (through tasks 1-3; 8, 9) and are the basis to develop whole-system models used for optimal water-grid design in WP6.1 and optimal water-grid operation in WP6.2 (task 4). It also contributes to the modelling part of the data-model assimilation systems tested in WP2.2. Finally, scenarios evaluated in the IGSM have to adhere to legal bounds and credible policies investigated in WP5 and provide the physical basis for evaluating the effects of legal policies and governance arrangements.

Time plan and division of tasks

Activity ↓ **Months→**	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Setup of hyper-resolution and scalable IGSMs for 3 case studies (PhD)								
2. Provide regional climate & socio-economic scenarios until 2100 (PhD)								
3. Provide baseline scenarios exposing current and future gap between water demand and fresh water supply for the case studies (PD)								
4. Use the developed models for sensitivity runs subject to various interventions (aquifer storage, recycled water injection, etc.) as a basis to derive fast whole-system models (PhD with staff from 6.1 and 6.2)								
5. Perform controlled field tests for two pilot sites: brine injection and brackish water extraction (PD)								
6. Based on 5: local (5-10m scale) modelling of groundwater velocities, transport and mixing processes at field sites and deriving an effective parameterization to be used for regional-scale modelling (PD)								
7. Include the results of step 6 in the regional-scale models (PhD)								
8. Run scenarios per case study, including the established AquaConnect water-grid. Compare water gaps with the baseline scenarios (PhD)								
9. Crash test sustainability of the system under climate extremes (PhD)								
10. Writing papers and PhD thesis (PHD and PD)								

Methods
We will employ state-of-the-art model codes for groundwater flow and transport[4,8] to seamlessly scale between regional and local resolutions. These allow for simultaneous evaluation of nested models of varying resolution in one model run. Up- and downscaling is achieved by parameterization methods for coarser resolutions than the existing data[5] (upscaling) and geostatistical methods for resolutions that are finer (downscaling)[6]. We will use massive parallelization techniques developed by our team[7,8] to deal with long simulation times and uncertainty assessments. We will provide regional climate and socio-economic (land use, GDP, population, water demand) scenarios up to 2100 for the 3 case studies by combining downscaled output from global climate models[9] with global socio-economic pathways[10] and land use scenarios[11,12]. To better represent brackish groundwater extraction and brine injection in the regional models, numerical experiments at existing field pilots will be conducted to understand salinity mixing processes, the role of heterogeneities and geothermal effects.

Contribution to AquaConnect deliverables
This WP 2.1 significantly contributes to different AquaConnect deliverables as the IGSMs are utilized to test regional effectiveness and robustness of solutions and to the design of the water grid.

- *Case-specific problem analysis*. The regional IGSMs are case-specific and, together with the regional scenario analyses, reveal if and where imminent and future problems of water scarcity occur for the three case studies.
- *Key-technologies*. The hyper-resolution and scalable IGSMs contribute to key digital technologies as they are based on the development of new seamless parameterization methods, efficient parallelization techniques and high-performance computing for variable-density groundwater modelling.
- *Governance instruments*. The IGSMs serve as a platform to governance/regulations for evaluating the effects of legal policies and governance arrangements.
- *Integrated case-specific solutions*. WP2.1 contributes to case-specific solutions by providing a testbed for the individual local solutions and establishing smart water-grids containing these solutions.
- *Scalable solutions*. The activities in task 8, where solutions are applied and evaluated regionally as part of a smart water-grid, provides insights in the scalability of solutions.
- *International Outreach.* Seamless scaling and the developed computational technologies are re-usable in model platforms used for international consultancy. The insights into the effects of aquifer storage, brine disposal and brackish groundwater exploitation are extremely beneficial for drinking water strategies in water scarce countries.

Role of users
Representatives of end users have actively participated in the design of the project. The provinces of Zeeland and Zuid-Holland and water authority Scheldestromen (WSSS) and drinking water company Dunea are contributing (in kind/cash) and their stakes are in obtaining instruments to support Water Management Plans for the future. They participate by delivering data, connecting their modelling instruments where possible and participating in the user committee. Deltares will support model development by supplying the most recent models, software and datasets, by knowledge exchange with researchers and by connecting the new insights to the currently used models.

Intellectual property
IP of models, data and methods developed within the project are jointly owned by the consortium as far as they are parties performing the research or contributing to it in kind/cash. IP is open to all users after the project has finished.

WP 2.2. Management of fresh groundwater resources using data-model integration
Project leader: Prof. Dr. M.F.P. Bierkens, Utrecht University **Co-applicant(s):** Dr. G.H.P. Oude Essink, Deltares; Dr. M. Karaoulis, Deltares **Requested research positions:** 1 PhD; **Duration of project**: 4.5 years

Scientific description of the WP

To manage fresh groundwater resources in a more sustainable way, we will develop a data-assimilation methodology which integrates different (geophysical) monitoring data with 3D variable-density groundwater models. These models predict the present status of fresh groundwater resources as well as the reaction to future climate and anthropogenic stresses over different time scales (from intensified groundwater extractions up to a slow sea-level rise) and different spatial scales (salinization processes like saltwater upconing under a well, up to land-use changes affecting recharge infiltration rates or lateral saltwater intrusion caused by sea-level rise). The outcome of this WP is a generic 'early warning' toolbox in which operational management of fresh groundwater resources over time is controlled though combining data-model integration, machine learning and model predictive control concepts.

Scientific challenge
An increase in competing claims for scarce water and peaks in water demand challenges the sustainable management of fresh groundwater resources, causing hick-ups in the freshwater supply chain and economic damage. Monitoring is often restricted to a few locations and data collected at a low frequency, while (coarse) variable-density groundwater

models are typically unable to capture the complex heterogenous nature of the subsurface and to accurately predict salinization processes. To improve the predictive ability of variable-density groundwater models, field data[14,15] need to be integrated better. The first challenge is to make the models fast and accurate enough to describe different temporal and spatial scales of saltwater upconing under wells, regional salinization caused by autonomous developments and climate stresses including sea-level rise and precipitation pattern changes. The next challenge is to automatically integrate data using data-assimilation methods. The third challenge is to assess appropriate monitoring plans, given the spatio-temporal characteristics of the salinization processes. The fourth challenge is to develop a framework where data and model are integrated and to evaluate whether these improved models lead to a better predictive capacity.

Contribution to other work packages

The system is piloted such that outputs and insights of this WP contribute to the case studies in WP7. On longer time scales, monitoring data will be used to improve modelling within WP2.1, while on shorter time scales, the operational management is supporting the water-grid in WP6.1 and optimal water-grid operations in WP6.2 (task 4). Applications of data-assimilation methodologies within pilots also encounters societal, economic and legal impacts, linking to WP5.

Time plan and division of tasks

Activity ↓ **Months→**	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Select sites where fresh groundwater resources need better management; collect data; analyze (legal) extractions practices and configuration								
2. Develop a detailed, yet fast, scalable 3D model for variable-density groundwater and salt transport								
3. Set up a (geophysical) monitoring plan with appropriate spatial and temporal characteristics								
4. Execute the monitoring and calibrate the scalable transient 3D models								
5. Set up a toolbox to incorporate monitoring data and model results								
6. Use the improved 3D models for prediction purposes								
7. Writing papers and PhD thesis								

Methods

We propose to apply our monitoring and data-assimilation framework at a drinking water company with a deep fresh groundwater lens (Dunea). We will use the recently developed parallel code[8] or the new code[4] MODFLOW6. Geo-electric, electromagnetic as well as fiber-optic methods are considered for monitoring[16-18]. An appropriate framework is developed for data assimilation of the newly received monitoring data as well as automatic update of the model in a sequential time-stepping procedure. The supervision team has extensive knowledge on geophysical monitoring techniques, inversion methods, optimization procedures, and variable-density groundwater modeling.

Contribution to AquaConnect deliverables

- *Key-technologies*. A generic toolbox (software and documentation) is provided that includes state-of-the-art data-assimilation, machine learning and model predictive control concepts, to be used to connect existing variable-density groundwater models to geophysical monitoring data to setup model predictive control systems.
- *Integrated case specific solutions.* This WP directly contributes to this deliverable by sharing hydrogeologic knowledge, local practical expertise, data and methodologies to achieve optimal model and data conditions.
- *International Outreach.* The generic toolbox can be used in international projects to design systems around drinking water extractions and Managed Aquifer Recharge in coastal water scarce regions around the world.

Role of users

Participation of drinking water companies and industry is required to share local (management) expertise on fresh groundwater resources in a historical perspective. Input from water authorities (WSSS, Delfland) and provinces (Zeeland, Noord- and Zuid-Holland) is needed for setting the regulations under which fresh groundwater resources can be manipulated. Drinking water company Dunea and KWR contribute to this research by cooperation with their pilot brackish groundwater extraction. Deltares will share (geophysical) monitoring techniques of different Technical Readiness Levels, parallel computer codes[8] and clipping toolboxes (iMOD-python) to ease the creation of scalable models.

Intellectual property

IP of models, data and methods developed within the project are jointly owned by the consortium, as far as they are parties performing the research or contributing to it in kind/cash. IP is open to all users after the project has finished.

5.2.2 Work package 3: Risk-assessment of cyclic water systems that include nature-based treatment and storage

WP 3.1 Risk-assessment of re-use in cyclic water systems
Project leader: Prof. A.P. van Wezel, University of Amsterdam **Co-applicant(s):** Dr. N. Sutton, Wageningen University; Prof. H. Rijnaarts, Wageningen University **Requested research positions:** 1 PhD, 1 Postdoc; **Duration of project**: 4.5 years
WP 3.2 Improving prediction of micropollutant transformation product formation in groundwater systems
Project leader: Dr. Nora B. Sutton, **Co-applicant(s):** Prof. H. Rijnaarts, Wageningen University; Prof. A.P. van Wezel, University of Amsterdam **Requested research positions:** 1 PhD; **Duration of project**: 4.5 years

Scientific description of the project/WP

Scientific challenges

In order to compensate for water shortages for municipal, industrial or agriculture water uses, multiple available alternative water sources can be used to replenish and store water[1]. These nonconventional sources might consist of municipal or industrial wastewater, brines, stored surface waters, sored precipitation, polder waters, cooling water or a mix of various alternative waters. For the re-use purpose, information will be required on the risks of contaminants and possible transformation products (TPs) present in the alternative sources during the re-use to evaluate the risks and the need to mitigate these risks[2]. Particular focus is placed on chemicals of emerging concern (CECs), including pesticides, industrial chemicals, pharmaceuticals, and household chemicals. CECs are currently found in existing groundwater aquifers used for drinking water production. Closing water cycles by sourcing water for alternative waste and surface water supplies increases the risk of accumulation of CECs in water cycles. Furthermore, current research and monitoring of water quality focuses on parent CECs, often neglecting the range of transformation products formed during biodegradation of CECs in the water cycle.

In this WP, we will study CECs and their TPs, examining their occurrence, fate during re-use, removal during additional technologies applied and ultimate risks to both workers, consumers and environment. We aim at a systematic investigation in both laboratory, field and case studies on the behaviour of CECs and TPs. TP formation is particularly researched in subsurface water storage systems where the variety of redox conditions (electron acceptor availability) and dissolved organic matter (DOC) affects CEC biodegradation and TP accumulation. Furthermore, we will evaluate the effects on the ecological system of the water re-use. We will study occurrence and abundance of species and functions present in non-cyclic and cyclic water systems, and generalize this in an ecological model for water re-use. In doing so, AquaConnect will contribute to implementation of the recent legislative development such as the EU Water Re-use regulation, and the creation of good and practical guidelines for end-users, such as drinking water utilities, industries, agriculture and involved authorities that have to decide on various options for water re-use.

Connection to other workpackages.

The results of this sub-project improve the understanding of risks from CECs in new circular water systems. The research identifies recalcitrant and problematic CECs and TPs from different water sources and different environmental conditions and determines ecological and human risks associated with closing water cycles. The results provide information on water quality, which can be coupled to the water quantity the scenario's as being developed in WP2. The identification and risk-assessment of the CECs and their TPs allows the implementation of tailor-made water treatment technologies within cyclic water systems, which will be developed within WP4.1. The development of these tailor-made technologies in combination with the risk assessment of the circular water system performed in WPs 3.1, 3.2 and 4.2 functions as input for the physical shape of the smart water grid including fit-for-purpose treatment at the appropriate location that is determined in WP6. Additionally, the risk assessment performed in this WP sets the legal boundary conditions for water reuse in cyclic water systems, as will be analysed in WP5. Overall, this sub-project delivers advanced insights into key water quality parameters, namely OMPs and TPs thereof, in order to support a clean, circular water cycle.

Time plan and division of tasks

Table 3.1. Activities for PhD1 and PD at UvA: Risk-assessment of re-use in cyclic water systems. Tasks 1-7 will be performed by the PhD, tasks 8 and 9 will be performed by a 2 yr PD.

Activity ↓ ***Months →***	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. The fate and risks of CEC in various water re-use situations will be evaluated based on High Resolution Mass Spectrometry, Next Generation Sequencing and Effect Based Monitoring analysis								
2. Evaluation mitigation options, e.g. how use of alternative sources, water pre-treatment by advanced and/or nature-based technologies etc. can lower occurrence of CECs in the re-use cases								
3. Identification of most problematic parent compounds which can be flagged as the chemicals that might hamper current intentions to reach a more circular use of water								
4. Evaluating the common properties that these chemicals have in the chemical universe								
5. Make suggestions how the risk evaluation and scenario's currently underpinning the registration and authorization of the chemicals can be adapted to prevent these chemicals hampering circular economy being on the market above critical emission volumes								
6. Generalization of lessons learned in practical and science-based guidelines for end-users								
7. Prospective regional-scale scenario's will be run to make water-dependent uses more fit-for-future under various drought scenario's								
8. Evaluate the effects on the ecological system of the water re-use in regional water grids								
9. Development of ecological model for water re-use								

Table 3.2. Activities for PhD2 at WUR: Improving prediction of micropollutant transformation product formation in groundwater systems.

Activity ↓ ***Months →***	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Selection of priority CECs based on literature review and review of monitoring data.								
2. Selection of priority CECs and TPs in water resources for aquifer recharge (with WP3.1)								
3. Microcosm experiments under different environmental conditions screening for TP formation and fate								
4. Comparison between TPs found in microcosm experiments and field monitoring data								
5. Column experiments to determine influence of shifting redox conditions and DOC amendment on TP formation, recalcitrance, and degradation (PhD).								
6. Identification of key microbial community using 16S rRNA gene and whole metagenome sequencing								
7. Selection of key conditions for CEC mineralization for bioremediation technologies								
8. Screening field locations for correlations between environmental conditions and TP formation (with drinking water companies and water authorities?).								
9. Manuscript and thesis writing (PhD).								

Methods

In this WP, 2 PhDs and one PD will research CEC and TP fate in circular water systems. The PhD at the WUR is more technological in focus, utilizing laboratory and field experiments to ascertain the fate of CECs and TPs in subsurface water storage systems (Table 3.2). Our research approach is based on applying advanced analytical techniques to degradation experiments in which we simulate groundwater environmental conditions to understand TP formation. To link biodegradation with microbial community composition and degradation capacity, we will rely on our expertise and current collaborations in analysing groundwater microbial communities. The PhD and PD at UvA focuses particularly at developing chemical and biological risk assessment strategies to understand the risks associated with circular water systems for both humans and the environment (Table 3.1) based on a series of case-studies provided by AquaConnect stakeholders. To evaluate the effects on the ecological system of the water re-use, we will study

occurrence and abundance of species and functions present in non-cyclic and cyclic water systems, where we will start with cases with a clear ecological function. Therefore, we will use the infrastructure that is currently being developed in both the ARISE and UNLOCK large scientific infrastructure, relying on e-DNA, acoustic, visual and radar signals. WPs 3.1 and 3.2 are executed in close collaboration, ensuring exchange of data, research questions, and methods among the researchers.

Contribution to AquaConnect deliverables

Sufficient water quality is a key prerequisite for designing robust water cycles. The research in this WP provides key insight into the fate and transformation of a key class of pollutants, namely CECs, that threaten water quality and thus form a threat to closed water cycles. As such, this WP significantly contributes to the different AquaConnect deliverables that were identified in section 3.8 (Fig. y).

Case-specific problem analysis. The identification of key CECs and their TPs in groundwater systems is vital for the drinking water companies in all 4 different regions that obtain their raw water from groundwater systems and allows these companies to adjust their current drinking water production strategy (deliverable 1). In addition, the identification of the CECs and their TPs allows to contribute to proper risk-assessment of current groundwater reuse initiatives as already initiated by the different drinking water companies and water authorities that participate in AquaConnect.

Key-technologies. The identification of key CEC and their TPs in cyclic water systems allows the development of key physical/chemical water treatment technologies that can be incorporated in smart water-grids for their tailor-made removal of problematic CEC.

Governance instruments. The output of this WPs functions as input to governance/regulations for mitigating risks and the definition of the operational window and permits for cyclic water systems.

Integrated case-specific solutions. Insights into the transformation of key CECs and their TPs in groundwater systems is crucial to select water sources for reuse and storage, assessing and mitigating the risks of reuse, and giving input to governance (deliverable 3). A combination of monitoring, fit-for-purpose water treatment and bioremediation technologies allows the integration of groundwater systems in the proposed smart water-grids in the different case-studies (deliverable 4).

Role of users

This project is executed in close collaboration with drinking water companies (Vitens, Dunea, Oasen, Evides, Brabant Water), KWR Water Research Institute and water authorities (Rijn & Ijssel, Vallei & Veluwe, Hoogheemraadschap Noord-Holland, Scheldestromen, Vechtstromen). We aim to work together with drinking water companies, KWR and water authorities in steering the selection of priority compounds and translating the results into recommendations for bioremediation technologies and monitoring approaches, to identify both current risk of CECs and their TPs in their reuse-schemes (deliverable 1) and provide solutions for their future smart water-grids (deliverable 4). The drinking water companies and water authorities will support this WP in-kind by facilitating field sampling campaigns to collect aquifer materials, providing access to existing water monitoring data and supporting sampling of monitoring wells to assess TP presence.

Intellectual property

All results will be in principle open access for the full consortium (IP domain I). From the research IP on natural removal and bioremediation approaches (though not likely) may arise for which a Specific IP domain type III can be created during the project when needed.

5.2.3 Work package 4: Chemical and physical technologies for fit-for-purpose water, sludge and brine treatment and management

WP 4.1. Fit-for-purpose treatment including brine management
Project leader: Dr. J. Dykstra, Wageningen University **Co-applicant(s):** Prof. W. de Vos, University of Twente; Prof H. Rijnaarts, Wageningen University; Prof. R.G.H. Lammertink, University of Twente **Requested research positions:** 2 PhDs, 1 Postdoc; **Duration of project**: 4.5 years

Scientific description of the project/WP .

A water-treatment combination of nanofiltration (NF) and electrodialysis (ED) will be developed that can be implemented on a decentralized scale to treat water "fit for purpose". (Fig. 6). NF will effectively remove organic micropollutants, colloidal particles, nanoplastics, viruses, bacteria, and divalent cations, whereas the electrodialysis step can be used to control the effluent salt concentration and ion balance of the treated water (water fit for re-use). In this WP, two PhD positions are defined to develop this treatment combination (Fig. 6).

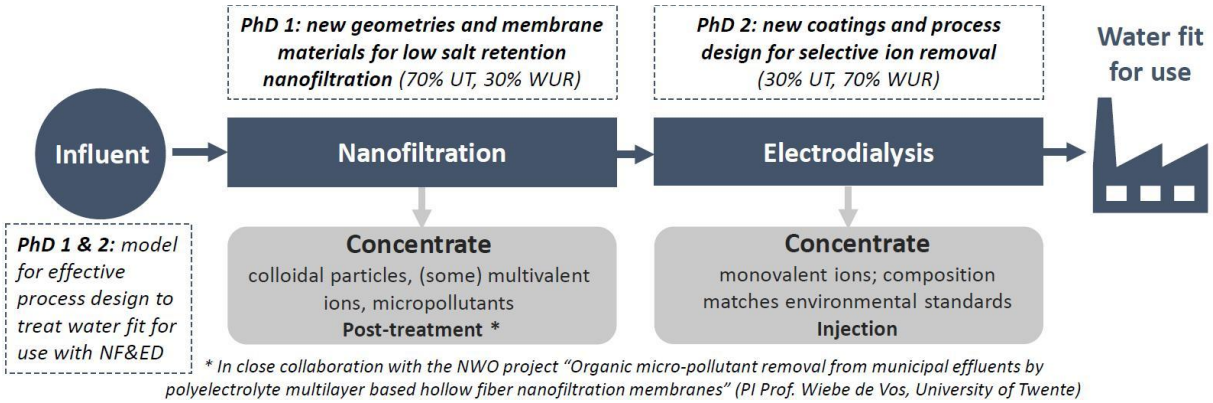

Figure 6: Overview of the workpackage

PhD 1 - New geometries and membrane materials for low salt retention nanofiltration

Traditional membrane technologies such as Reverse Osmosis (RO), remove pollutants but will also remove most of the ions, leading to the production of a highly saline brine, and a permeate with an undesired low salinity. Moreover, RO membranes require extensive pre-treatment due to spacer fouling and their low resistance against chemical cleaning. A very promising alternative is provided by polyelectrolyte multilayer (PEM) based hollow fibre (HF) membranes, that due to their HF geometry and high chemical stability can be used without pre-treatment[1]. Moreover, we recently developed a unique new type of membrane, based on asymmetric PEMs, that allows very efficient removal of (micro)pollutants (>98%), combined with very low salt retentions (<20% for NaCl)[2]. These separation properties are highly desirable as it would allow effective removal of pollutants without producing a saline brine, and without affecting the ionic balance of the permeate. Still, such properties will only be relevant when the membrane can be used as effectively as possible. In this project, we aim to change the membrane geometry to an outside-in geometry, almost doubling the effective membrane surface area without increasing the membrane costs or the module volumes. This does require active separation layers that have a high mechanical stability, to withstand the abrasion that takes place on the outside of a hollow fibre. Such stability can be obtained by dense crosslinking, as is done in traditional RO, or by embedding solid nanoparticles[3]. Together with a new module design, to further optimize mass transfer in this novel geometry (for PEM membranes), this membrane will be able to apply its unique separation at the low cost and high efficiency required for the envisaged large scale applications.

PhD 2 - New membrane coatings and process designs for selective ion removal

For effective water re-use, technologies are required to control the ionic composition to meet the requirements of the water user. Several technologies are commercially available to reduce the concentration of all ions, which can be employed to treat, for example, brackish groundwater. In this project, we will focus on the development of electrodialysis (ED), a desalination technology using an electrical field as the driving force. A large advantage of this technology is its flexibility, with the exact degree of desalination being controlled by the applied electric driving force, allowing an effluent with exact "fit for re-use" salinities. Still, it is not just the overall salt concentration that matters, for many applications, ranging from agriculture to drinking water, the exact ionic composition is crucial. Specific separations are considered, including the separation between monovalent and divalent ions, and the removal and recovery of phosphate. In the design of this process, we will focus on the effluent requirements of the desalinated water, as well as the environmental compatibility of the concentrated stream. Recently, layer-by-layer (LbL) polyelectrolyte coatings on commercial ion exchange membranes have shown an improved selectivity for monovalent ions compared to uncoated membranes (5.4 vs. 1.4)[4,5]. These LbL-coatings allow tunable selectivity. In this project, we aim to explore various LbL-coatings, in close collaboration with PhD 1, to tune selectivity, not only of monovalent over

divalent ions, but also between various monovalent ions. We aim to develop a toolbox with several membrane coatings, which are chemically and mechanically stable, and which can be employed for water treatment in ED, operated in combination with NF. Furthermore, we will expand our current physics-based ED models with a theoretical description of LbL-coated membranes by using different space-charge models.

Joint research effort in cooperation with PD: user-friendly design model

To propose balanced treatment combinations with NF and ED, a user-friendly computational model will be developed that proposes for each specific case an optimized decentralized treatment system. This optimized system should meet the constraints dictated by the water user and the environment (for brine discharge). To that end, the model must use advanced, physics-based, membrane models to describe multi-component mass transfer across ion exchange and NF membranes, including the effect of boundary layers. These models exists,, and a theoretical framework to jointly evaluate NF and ED is also available. PhD 1 and 2 in collaboration with the PD will expand this framework with a physics-based description of LbL-coated ion-exchange membranes, and with experimental data of performed experiments (in this collaboration).

Scientific challenges

- Development of a mechanically stable asymmetric PEM membrane, based on outside-in hollow fibre membranes, will directly lead to highly efficient water filtration from nearly any source without the creation of a problematic saline brine (PhD1)
- Coating of ion-selective layers on membranes to achieve selective removal of specific ions in mixtures with divalent and monovalent ions, and in mixtures with monovalent ions (PhD2)
- Development of a physics-based process model to propose optimal designs including NF and ED steps to meet specific effluent requirements (PhD 1 and 2)

Methods

Mechanically stable PEM's (for NF, PhD 1) will be studied on model surfaces (as studied by ellipsometry and AFM), and membranes (as characterized by water flux, ion and pollutant retention, and effectiveness under prolonged abrasion). Dedicated support membranes will be produced in a specialized membrane spinning line and potted in in house designed modules. All required equipment is available at the UT. Transport across coated ion exchange membranes will be studied in a lab-scale ED system. Furthermore, experiments will be conducted to determine the membrane resistance, the chemical affinity towards certain ions and the chemical charge. All required equipment is available at WUR.

Time plan and division of tasks

	6	*12*	*18*	*24*	*30*	*36*	*42*	*48*
PhD 1: New geometries and membrane materials for low salt retention nanofiltration								
Design mechanically stable separation layer								
Development of support membranes								
Module design								
Operation on larger scales, combined with ED, including model design								
PhD 2: New membrane coatings and process designs for selective ion removal								
Coating of functionalized surface groups on ion exchange membranes								
Development of a theoretical model								
Operation on larger scales, combined with NF								

Connection to other workpackages

The identification of harmful chemicals in cyclic water systems in WP3 will steer the design of the newly developed NF and ED membranes for tailored removal of these harmful chemicals. The expected removal of harmful chemicals will determine the feasibility of new water resources identified in WP2 to be used in a regional water grid. Ultimately, our fit-for-purpose treatment technology will be a key-stone in the complete water-grid, as developed in WP6.

Contribution to AquaConnect deliverables

Case-specific problem analysis. Based on the case studies, we will identify several specific technological challenges to treat water fit for purpose (with different feed water composition, different user requirements). These examples require, preferably, differently dimensionalized combinations of NF and ED. *Key-technologies.* The newly developed NF and ED membranes with unique separation properties, will allow a highly efficient process that could treat large water volumes of nearly any source, to produce water free from contaminants at the desired salinity with a strongly reduced saline brine production. *Integrated case-specific solutions.* In this WP, we propose an innovative general treatment method to produce water fit for purpose. Our experimental findings will be integrated in an existing (but

expandable) model, which allows us to design, depending on the user requirements and the feed water composition, an effective water treatment system. We will use this model to design specific solutions for each case.

Role of users
Technology developers, such as NX Filtration and Nijhuis Industries, will be closely involved in this project, with active transfer of knowledge taking place to facilitate quick uptake of this technology in the market and AquaConnect smart water-grids. The possible end-users of this technology, including the water authorities, drinking water companies etc, will guide the project by providing the desired separation properties that would be relevant for their applications.

Intellectual property
All results in these workpackages will be shared with partners that assign to that domain during the project, where IP councillors of NWO-TTW and researchers involved will arrange agreements for transfer and licensing with parties involved (concerning access to knowledge and financial arrangements). All information generated will be made publishable after protective arrangements (Patent application, License agreement) have been made, and publication will be allowed at the latest 6 months after submitting a request for this to the IP domain related parties. (Type III domain)

WP 4.2. Managing and engineering quality effects of effluents, brines and sludges for application in soil and groundwater

Project leader: Prof. dr. ir. Sjoerd E.A.T.M. van der Zee, Wageningen University
Co-applicant(s): Prof. Huub Rijnaarts, Wageningen University; Dr. Xiaomei Yang, Wageningen University; Dr. Nora Sutton, Wageningen University; Dr. D. Gijsbert Cirkel, KWR Water Research Institute
Requested research positions: 1 PhD; **Duration of project**: 4.5 years

Scientific description of the work package

Re-use of treated water and brine (up-concentrated nonconventional water that may be brackish/saline or otherwise contaminated) as irrigation water for food/non-food primary production and the use of residual sludge for soil-improvement can be a sustainable way to reuse water and related resources, but can potentially result in environmental and food chain contamination. Both the type of contaminants and adverse consequences are diverse and concern different environmental compartments, such as plants/crops, soil, surface and groundwater. Accordingly, re-use of these waters and sludges must consider adverse environmental effects and sustainability, i.e. to set treatment requirements prior to use. Additionally, the potential beneficial effects of this reuse on water quality and soil fertility needs to be determined. An integrated sustainability assessment tool for these compartments is unavailable or has a limited functionality. This WP combines at the side of risks state-of-the-art insights and tools on i) toxicokinetics and bio-availability/accessibility; ii) biogeochemical interactions of contaminants in soil and water flow and chemical transport via ; iii) overland flow; iv) leaching into and through saturated groundwater and; v) losses to the atmosphere, and relates this to various quality standards. On the side of soil quality improvement, carbon capture and carbon/nutrient ratios to stimulate agro-production will be addressed. To enable a broad range of applicability both aspects will be addressed in the context of The Netherlands and in the more extreme context of 'focusing the sustainability tool' towards greening marginal lands (e.g. coastal deserts) as occurring in the Middle East. The extreme case will help to validate the model and make it robust for a wider set of conditions. As the soil properties in the M.E. are not comparable to those in e.g. The Netherlands dedicated parametrization experiments have to be carried out.

Scientific challenge
The present WP broadens the scope of the sustainability concept of Boekhold (1992)[1] to a diverser set of contaminants. The sustainability assessment aims to protect the environment for both short and long term, integrating environmental compartments as well as the large diversity of contaminants and specific pathways, such as overland flow[2]. In this WP, the Framework for Integrated Sustainability Assessment FISA, as extended by Van Der Zee et al. (2014)[3] and Magnone et al. (2019)[4] is further developed towards compound specific behaviour of contaminants of emerging concern (CEC) (day care products, veterinary and human pharmaceuticals, endocrine disruptors, pathogens etc) and adsorbing and degrading substances, such as solvents, hydrocarbons, persistent organic pollutants, and pesticides. Part of the framework are current environmental standards that represent agricultural yield reduction or crop quality damage, and soil and groundwater quality standards that are the reference to test sustainability. The envisioned extension of the concept comprises environmental behavior (mobility, bio-availability/accessibility, persistence and toxicity), suggestions for standards if not available compilation of sketchy or suggestions for lacking fate parameterization, by data assimilation. The selection of compounds for experimentation includes soluble cations to enable a proof-of-principle (Van Der Craats et al., 2020)[5] for sodicity, and compounds chosen with the end-users group, which consists of drinking water companies and industries. Synergy is obtained with NWO projects (RUST, SUSPECt, SURFLAT), e.g. regarding overland flow and the fate of veterinary pharmaceuticals. Numerical modelling with FISA maps the parameter space (half-life, adsorption affinity/retardation factor affecting mobility, uptake parameter, toxicity) for major soil types, geohydrological conditions, and land use, to reveal major processes and hazards. Following the numerical sustainability assessment, the aims is to capture fate and sustainability in simple metrics, figures and tables,

similar as in the well-known leaching requirement (Richards et al., 1954)[6] for salinity, and generalizations thereof by Stofberg et al. (2016)[7] and Cornelissen et al. (2019)[8], indicating the potential hazards and benefits of reusing treated water, brine or sludge.

Contribution to program

The experimental and modelling parts will directly contribute to the needs of a risk and sustainability assessment of potentially hazardous components in new water resources and sludges used in cyclic water systems and for soil-improvement. In this program, there are direct links with WP3.1 and 3.2, that will provide fundamental understanding about the fate of contaminants in cyclic water schemes that needs to be integrated in this the model-tools developed in this WP. With WP4.1, a joint appreciation is possible to determine which contaminants should be emphasized in view of relatively easy to eliminate ones (by treatment). It is envisioned that the insights developed in this WP are used in the case studies, demonstration cases and in basic understanding at the interface of water quantity and water quality. The WP provides tools and insights that are crucial for sustainability assessments as required by authorities and industry in avoiding liability suits. Also, they are expected to become an important tool in the consultancy sector.

Time plan and division of tasks

Activity ↓ ***Months →***	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Parameterisation by data-assimilation and soil-transport experiments								
2. Greenhouse experiments to determine effect sludge on soil quality								
3. Modelling, extension of FISA and numerical modelling								
3. Definition of sustainability indicators								
4. Practical tool development, developing simple guidelines/formulae for practical assessment by laymen								

Methods

This WP comprises experimentation in laboratory, greenhouse, and in the field, with a team consisting of Dr. Gijsbert Cirkel (KWR), Dr. Xiaomei Yang and Dr. Nora Sutton (WUR). Chemical parameterisation is done with laboratory experiments for sorption behaviour of selected compounds and for soils as selected together with the user-committee. Mobility of the diverse contaminants is investigated with column experiments in laboratory and greenhouses, and for some finer textured soil types in the field, in-situ, the latter to check the transferability of various parameters to undisturbed soils. Persistency studies will involve lab assays following standard (EU Focus) procedures and artificial soils and, additionally, with the selected real Dutch soils in greenhouse pots and field. To determine plant uptake and the effect of applying sludge to increase soil fertility and enhance plant growth, plant growth experiments will be performed in pots in the greenhouse and validated in the field. All infrastructure is available as is the case for licences to work with pathogens and other licence requirements. Modelling with FISA, is done after extension with new functionalities (e.g., for passive/active plant uptake; degradation; multicomponent interactions where needed; volatilization; overland flow). Modelling concerns demonstrating the validity of concepts, identification of needed improvements, and acquiring understanding of the complex integrated systems.

Contribution to AquaConnect deliverables

This WP will contribute to the AquaConnect deliverables (Fig. 2) by providing insights in the key tools for sustainability assessment of water, brine and sludge reuse (deliverable C), which are needed for the reuse of these streams when integrated in contextual solutions for the utilization cases (deliverable D) and demonstrations (deliverable E)

Role of users

This WP will cooperate with various stakeholders to determine the risks and benefits of reusing treated water, brines and sludges. In the Higher Sandy Soils, Vitens aims to determine the quality effects of recharging aquifers with treated water and disposing brackish brine, and will provide water quality parameters as input for the envisioned FISA model. In the province of South-Holland, Oasen and Dunea will provide monitoring data to better understand the impact of subsurface brine disposal on the subsurface water quality. In Qatar, as part of the international outreach, Shell participates in the program 'Greening the Desert', and wants to determine the long-term potential hazardous effects and benefits of using treated water and sludge for crop irrigation and soil improvement for food and non-food production. As such, Shell will function as a bridge between AquaConnect and the 'Greening the Desert' program and supports in translating the results obtained by lab-experiments and modelling towards international application.

Intellectual property

This WP provides open-source information, data, and protocols with a citation clause to NWO (this project). Free use and no patenting is expected, to enable use in economically challenged environments or countries. Release of all material to other than project participants will be according to the Consortium Agreement.

5.2.4 Work package 5: Integrated assessment and societal change

WP5.1. Socio-economic analysis of circular water governance
WP5.2. Legal- and policy assessment for circular water governance
WP5.3. Science-policy interaction, stakeholder involvement and upscaling

Project leader: Prof. D. Huitema, Vrije Universiteit
Co-applicant(s): Dr. H. K. Gilissen, Utrecht University; Dr. T. Terpstra, HZ, Deltares
Requested research positions: 2 PhDs + 1 PD, plus links to ongoing existing PhD projects
Duration of project: 4.5 years

Scientific description of the work package .

Water shortages can cause major societal disruption. To enhance socio-hydrological resilience, it is imperative that regions start preparing for situations in which freshwater is insufficiently available to serve critical segments of society and the economy for certain periods of time. Without greater resilience to ever more extreme climatic and hydrological events, increasing societal and economic risks and damages loom. A step change is needed in the way freshwater is managed and conserved, including innovative solutions that enhance regional resilience and can be scaled up and exported to other parts of the world. The development and testing of innovative technologies in the project AquaConnect will occur in direct collaboration with stakeholders and end users. This work package comprises an integrated assessment of financial, economic, legal and political feasibility and the conditions under which upscaling becomes possible, to ensure critical legal-institutional embedding and societal and policy support. The figure below presents the approach taken in this project.

Scientific challenge

The central question in this work package is: "which socio-economic, political, legal and policy challenges could arise when it comes to the development and implementation of novel water management technologies aimed at enhancing regional socio-hydrological resilience, why do such challenges arise, how can these be influenced or navigated, and which conditions need to be created for local innovations to be scaled up?" To date, little existing academic work has looked into the issue of circular water management, and none of the existing research has paid much attention to legal and economic considerations underlying the required transitions. There is an important knowledge gap in existing assessment procedures that are typically compartmented and conducted in isolation instead of in an integrated manner bringing all the relevant aspects together into a unifying framework. Separate procedures exist for (strategic) environmental, economic and social impact assessments. None of these are linked to more qualitative policy, legal and political science assessment approaches. Thus, scientifically, the challenge is to connect multiple ongoing debates about *integrated assessment*[1]. In this work package we will build on suggestions made to achieve more integration[6,7]. We will also connect to ongoing work on *transitions in water management*[2] and institutional change[5] which investigates the conditions under which certain innovations can be realized politically, and has pointed out the important role that pilots and experiments play in attaining larger scale changes. We also connect to ongoing work on *barriers and lock-ins* in water governance regimes[3,4] which seeks to understand the complex interactions between changes in technological systems, institutional arrangements and behavioral practices in the water sector. For each of these fields, our project will draw on leading contributions, and offers an opportunity to make novel contributions toto outstanding debates. As to the above, empirical studies in the four selected case study areas will be at the heart of this work package.

Scientific Context

We connect to at least three ongoing academic debates. In the debate about integrated assessment, various shifts have occurred in the past decade, notably an increase in focus on local and regional experiments, the involvement of stakeholders, and the facilitation of learning processes based on multiple problem perceptions – but how to best organize problem structuring work and connect it to political decision making is still a practical challenge[1]. In the debate about transitions in water management[2], much is now known about the strategies that actors can apply to affect policy change, but further work to unpack the societal dynamics underpinning barriers[3] to such transitions, and lock-ins that affect them, is urgent as is work on the dynamics of upscaling from local experiments (see for instance Siebenhüner et al., 2019[4] about the NWO funded project ADAPT-LOCKIN). In the literature about institutional change finally, institutional change processes have either been treated has fully endogenous or fully exogenous, with an urgent need to understand the dynamics between these impulses[5].

Time plan and division of tasks

Two PhD students and one postdoctoral researcher will be appointed in this project. Moreover, an existing PhD at the HZHZ (co-supervised with UU) will work on the upscaling dynamics from pilot projects in The Netherlands (ongoing project, related to the work of the VU Postdoc and project 5.3).). Wageningen Environmental Research (dr. Koen Wetser) will use a significant part of their available time under the project to produce scenarios for the supply and

demand of fresh water (which will feed into the work of the VU PhD student in project 5.1). For dissemination and utilization purposes, Deltares will invest in developing a practitioners' guide in close cooperation with stakeholders.

WP 5.1. Socio-economic issues

The first PhD student (Project 5.1; VU) will focus on the economic analysis of sustainable circular water governance systems. Insight will be provided into the costs and benefits of regional freshwater provision under increasingly extreme events, in particular the economic risks and potential damages from interruptions in freshwater provision under policy inaction. To this end, a hydro-economic model will be developed that explores the potential net economic benefits associated with innovative circular water management technologies that help to secure water supply in the future under different climatic conditions, and a practitioners' tool to assess the socio-economic impacts of these technologies. Besides using market-based valuation approaches, also non-market based valuation will be employed to account for risk behavior and risk aversion under different climate change scenarios and extreme events.

Activity ↓ Months →	6	12	18	24	30	36	42	48
1. Development and estimation of damage functions for economic activities under various scenarios/extreme events	■	■	■	■				
2. Economic valuation of the non-market benefits of freshwater provision under various scenarios including extreme events	■	■	■	■	■			
3. Development and operationalization of a hydro-economic model to assess the economic impacts of extreme events (baseline scenario of policy inaction) and innovative circular water management measures (policy intervention scenarios) on the regional economy in case study areas	■	■	■	■	■	■		
4. PhD thesis published (including thesis HZ PhD)							■	■

WP 5.2 Legal and policy issues

The second PhD student (Project 5.2; UU) will focus on the assessment of relevant legal and policy issues. The work will comprise an integrated analysis and evaluation of current and future legal and policy frameworks (institutional, instrumental and safeguarding dimensions) at local/regional, national and (if relevant) supranational levels. This research will be complemented with in-depth empirical studies in the four selected case study areas. On the basis of comparative analysis, also insights in potential alternative frameworks that have been adopted elsewhere will be used, paying special attention to the novel technologies that will emerge from the work in AquaConnect. This work will contribute to the formulation of recommendations for the selected cases specifically, and for the improvement of existing overarching legal and policy frameworks to foster regional socio-hydrological resilience in general. Results of WP 5.2 will be used as input for dissemination and utilisation purposes in WP 5.33.

Activity ↓ Months →	6	12	18	24	30	36	42	48
1. Overview of existing legal and policy arrangements on circular water management, both at the 'overarching' levels (EU, national) and tailored to the case study areas.	■	■						
2. Study of legal and policy instruments that can incentivize circular water management, typology of instruments, and framework for assessment.	■	■	■	■				
3. Study of effective legal and policy instruments in actual use across the globe with lesson drawing.	■	■	■	■	■	■		
4. PhD thesis published							■	■

WP 5.3 Science-policy interactions, stakeholder involvement and upscaling

The postdoctoral researcher (Project 5.3; VU) will bring expertise in science-policy interactions, experience in the organization of co-production with stakeholders, and expertise on the role of experiments and pilots in creating larger scale societal change. The postdoc will be responsible for the study of upscaling dynamics around circular water projects, and will play an active role in the organization of workshops and coordination between WP5 and WPs2, 3, 4 and 6. The postdoc will also be responsible for producing hands-on guidance for stakeholders in The Netherlands on how to view the economic value of circular water governance and how to cope with policy and legal challenges. To that end, the postdoc will contribute to the development of an integrated assessment tool. To ensure active collaboration with WP5 and to build on the expertise at Deltares, the postdoc will be based at Deltares for one day per week. In order to optimize dissemination and utilisation, parallel to the postdoc's work and that of the involved PhDs, Deltares will develop a generally applicable practitioners' guide that will be helpful to stakeholders in developing and implementing arrangements for circular water governance. This practitioners' guide will be developed in close collaboration (co-production) with stakeholders in the four selected cases, and its practical applicability will be recurrently tested in those cases throughout the course of the project.

Activity ↓ *Months →*	6	12	18	24	30	36	42	48
1. Workshop to discuss implications of legal and policy arrangements for possible technologies, connecting local stakeholder to national lawmakers	■	■						
2. Two workshops, to discuss damage functions from extreme weather events for different sectors, and to discuss foreign legal and policy innovations that could inspire the Dutch situation.	■	■	■	■				
3. Workshop on economic valuation results and potential instruments with regional stakeholders and national policy makers.	■	■	■	■	■			
4. In depth study of the political and bureaucratic dynamics that enable transitions in legal and policy frameworks in relevant regions, also paying attention to public perceptions.	■	■	■	■	■	■		
5. Workshop to discuss draft practical guidance on the integrated assessment of alternative technologies and the relevant political and bureaucratic dynamics to attain circular water systems.	■	■	■	■	■	■		
7. Guidance document on the integrated assessment of circular regional water systems and legal, political and bureaucratic dynamics (postdoc VU, with inputs Phd students UU, HZ and Deltares)	■	■	■	■	■	■	■	■

Methods
The methods foreseen to be employed include systematic literature reviews, economic valuation and hydro-economic modeling, cost-benefit analysis, choice experiments, Qualitative Comparative Analysis (QCA), legal analysis (doctrinal, empirical and comparative), interviews, and focus groups.

Links to other work packages
WP5 will closely work together with WPs 2,3, 4 and 6. In terms of the collaboration with WP2 and 3, it is expected that WP5, within the framework of the selected cases, will provide for stakeholder involvement and expert advice that delivers rapid feedback on societal feasibility, methods for and outcomes of integrated assessment of such technologies, and guidance in the implementation and upscaling of such technologies in and beyond the case study areas. The postdoc at the VU will be responsible for coordinating the interaction between WP5 and WPs 2, 3 and 6. There will be a close connection between the WPs, as the research focus in and outcomes of WP5 will be closely discussed with stakeholders (co-construction).

Contribution to program
The project will identify pathways to transformative institutional change and effective and legitimate regional socio-hydrological resilience in water governance, identify successful examples of transitions towards circular water governance elsewhere, identify cost-effective policy instruments that facilitate such a transition, and identify key drivers, possible barriers and success factors to facilitate the necessary institutional-economic change towards a sustainable and resilient circular water governance system.

Role of users
WP5 pays specific attention to the situation around brine disposal and brackish water extraction in the province of South-Holland, the reuse of water in Zeeuws-Vlaanderen, the use of marginal water in the Higher Sandy Regions, and the intrusion of saline water due to man-made infrastructures in the region of Amsterdam and South Holland. The work package will closely interact with the other work packages in AquaConnect so as to provide (i) early warning signals about socio-economic feasibility and broader stakeholder and end-user support challenges, and (ii) insights in considerations and arguments that might improve the longer-term feasibility and support for innovation in circular water governance systems. The project is a knowledge co-creation initiative, meaning that the relevant stakeholders in the mentioned case study areas will be directly and right from the start involved through their membership of an Advisory Committee to identify the relevant policy questions, direct the research to answer these questions, give feedback during the project on preliminary findings, suggest opportunities for innovation uptake in The Netherlands, advise to regulatory societal structures in the international twinning collaborations (especially Qatar, Chili, Vietnam and Bangladesh, and the water sector BlueDeal Program of international knowledge dissemination (see WP7) and recommend ways to communicate the findings with other stakeholders and policymakers (e.g. through workshops).

Intellectual property
Data and results of this WP will be in principle open access for the full consortium (IP domain I)

5.2.5 Work package 6: The digital smart water-grid

WP 6.1. Robust optimisation of future smart water grids at scale: harnessing heterogeneity of supply and demand through centralised and decentralised decision systems

Project leader: Dr. E. Abraham, Technical University of Delft
Co-applicant(s): Dr. S. Shariat Torbaghan, Wageningen University; Prof. dr. N. van der Giessen, Technical University Delft, Prof. dr. H. Rijnaarts, Wageningen University
Requested research positions: 2 PhDs; **Duration of project**: 4.5 years

Scientific description of the work package

Maintenance and replacement of existing centralized water infrastructure is becoming increasingly expensive[1]. A solution is the implementation of resilient and flexible water supply systems at different scales. One of the main benefits of this approach is that water is delivered at the required quality of the user[1], avoiding treatment and transport costs. The transition to water supply systems which can deliver fit-for-use water requires changes in the existing water transport infrastructure and addition of new centralized and decentralized infrastructure. This workpackage will develop a robust decision-support toolbox that can generate reliable long-term water system planning, with no-regrets principles explicitly embedded. Formulating integrated local water grids as a solvable optimization problem is necessary but unprecedented. Work on pipe topology and sizing[2] needs to be extended for integration of water treatment technologies and transport options. New modelling approaches are needed that reflect the physical characteristics of water transmission and treatment technologies at the accuracy for realistic long-term planning, while staying computationally feasible. Decentralized uptake of supply technologies at the local spatial scales is needed to characterize demand uncertainty for centralized grids, for which seamless integration of scalable agent-based approaches are required[3]. Spatial bottom-up clustering of users and parameterizing their demand by downscaled socio-economic, climate and policy boundaries (from WP2.1) is needed for uncertainty modelling. Tailored methods that have reasonable computational complexity are needed to perform optimization and sensitivity analysis, and to make the proposed optimization of water grids applicable in different contexts. Novel methods to incorporate policy decisions regarding water technologies and transport options within water system planning need to be developed. The feedback loops between water demands, water availability and policy to deal with these changes need to be explored through sensitivity analysis.

Connection to other workpackages

The tools created in this work package contribute to the overall AC program by linking to work packages WP2.1, WP4, and WP6.2/3 . WP6.2, which develops real time control and monitoring tools, can utilise the water grids generated in this work package to be compared with the performance of current water distribution networks. The tools developed in WP61 will be a building block of the integrated framework in the redesign of the Higher Sandy Region (WP6.3), and so useful to other regional water planners and designers. Large water users, water authorities and drinking water companies can tailor the planning algorithm to generate solutions to other regions.

Time plan and division of tasks

Activity ↓ Months→	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Screening of case studies to identify infrastructure planning problems								
2. Set up spatially and temporally detailed model of current water grid								
3. Build a networked database of user types and apply, bottom-up, clustering algorithms to parametrize and aggregate demand patterns								
4. Develop future water demand patterns								
5. Generate stochastic decentralized decision support for grid expansion								
6. Formulate long-term dynamic, water grid expansion planning problems								
7. Develop a data-driven scenario generating technique using supply scenarios (WP2.1), and results in step 5								
8. Formulate robust versions of grid expansion problems by combining stochastic optimisation and scenario reduction approaches								
9. Develop framework to investigate the sensitivity of infrastructure to implementing various regulatory alternatives								
10. Writing papers and PhD thesis								

Methods

Water users will be clustered by their temporal patterns of water use, water quality requirement, and geographic location using data-driven approaches and simple process-based models of different water user types (Task 1: Phd1, PhD2). Post code level open data on water use as well as user consultation, and consumption models will be curated, screened and validated to generate demand patterns at different temporal and local spatial scales (Task 2: Phd1 and Phd2). Novel clustering methods for water use by socio-economic parameters[4] as well as bottom-up aggregation models, akin to ones for devising local energy demand profiles for renewables integration[5], will be developed for a

regional water demand model (Task 3: PhD1). Machine learning with network-based models will be used to tease out dependencies between climatic drivers and availability of supply as well as between demand and socio-economic drivers (Task 4: PhD1). Promising methods for representing likelihoods and preferences of water users to adopt technologies[3] will be employed to simulate multitude of scenarios in Monte-Carlo settings, where end-user water demand is quantified, also producing data for uncertainty characterization in optimization of supply pipe networks. This analysis will reveal how new technologies, efficiency strategies and decentralized decisions propagate across space and how temporal patterns of demand change in future[6] (Task 5: PhD1). Dynamic optimization of centralized infrastructure expansion over the long run[7] will be formulated as a multi-stage stochastic optimization problem[8] that considers uncertainties in the system (Task 6: PhD2). Uncertain input parameters will be described probabilistically, for which computationally tractable discrete version will be derived through scenario generation approaches (Task 7: PhD2). [8] Unique properties of water transport systems will be used to apply a range of problem reformulations to make them computationally tractable; convex-relaxations[9,10] and Fortuny-Amat McCarl Linearization techniques[11] will be used (Task 8: PhD2). We will develop analytical or numerical sensitivity analysis frameworks[12] to assess the impact of different uncertain factors on the development of the water infrastructure in the long-term (Task 9: PhD1 & PhD2). This workpackage will generate appropriate abstractions for peak demand representation, spatial and temporal aggregation of demands based on the required level of detail for long-term design optimisation. We will then employ an Optimisation-Simulation framework, where optimisation is performed with simpler models and performance is assessed with more detailed simulations with finer diurnal time scales and nonlinear dynamics.

Contribution to AquaConnect deliverables

Case-specific problem analysis. The screening and optimisation of key water supply infrastructure planning in the 4 case-study regions will allow local utilities to match water supply and demand in future, sustainably and cost effectively. ***Key-technologies.*** Novel approaches for characterizing uncertainties in localized supply and demand will be developed together with mathematical optimization approaches for complex decision making problems. As such, planning problems regarding design of water transport and storage infrastructure, treatment and decentralized/localised use and re-use can be answered. ***Integrated case-specific solutions.*** For different case studies, a spatially explicit local water distribution model will be developed to fit within RTC model (part of NHI) defining regional level infrastructure. With regional infrastructure as boundary conditions on local water availability of different qualities, local water provision networks will be optimised to meet demand by supply from nonconventional water sources, to create alternative local water provision grids that will be climate robust, energy efficient, and cost effective.

Role of users

This WP will be executed in close collaboration with drinking water companies and water authorities in all four cases, where these stakeholders will be involved in the screening of specific water system infrastructure planning cases. These will be optimised to identify locally relevant and most feasible investments needed to build a more robust water system of the future. Together with HZ University of Applied Sciences and Deltares, the water authorities and drinking water companies will support the PhD researchers in-kind by facilitating access to major water users in industry and agriculture within the region, and already existing data within the NHI framework.

Intellectual property

IP associated with of methods, models and data developed within this WP will be in principle open access for the full consortium (IP domain I).

WP 6.2. Real-time monitoring and model predictive control of smart water-grids
Project leader: Prof. Dr. Ir. J.P.M. Voeten Eindhoven University of Technology
Co-applicant(s): Dr. M. Lazar, Eindhoven University of Technology; Dr. D. Goswami, Eindhoven University of Technology; Prof. dr. P.M.J. van den Hof, Eindhoven University of Technology
Requested research positions: 1 PhD, 1 Postdoc; **Duration of project**: 4.5 years

Scientific description of the work package

Modern water grids[1] are currently undergoing a substantial transformation[2,3,4]: water supply/demand and operation of electrical pumps/valves become more dynamic due to harsher weather, limited resources and dynamic electricity prices with coupling update rates in the order of tens of minutes, needed in piped infrastructure, to those of treatment plant and water-way infrastructure in the order of hours to days, to those of natural storage systems such as surface water basins and artificial recharge and dune infiltration systems, in the order weeks and even months. This variation in dynamics in decentralized local water grids very much resembles (though at different time scales!!) combined decentralized-centralized power supply systems having diverse and different power and storage capacities (with also time variances of several orders of magnitude, i.e. from pico-seconds to hours). Hence, grid modeling knowledge is transferred here from energy to water sector. To this end, WP 6.2 will develop a real-time monitoring and model predictive (*closed-loop*) control framework for optimal water-transactions in smart local water grids as envisioned in AquaConnect. The envisioned **Water Embedded Model Predictive Control (WE-MPC)** framework (Fig. 7) will compute the optimal storage distribution in the reservoirs for local water-grids of size in the range of 20x40 km^2 for meeting

future water demand connecting the shorter time-scale (tens of minutes), to those of the longer time scales (hours, weeks, to months) of the non-piped and natural water infrastructure using model-based predictions and online optimization based on status feedback of the grids (reservoirs capacity).

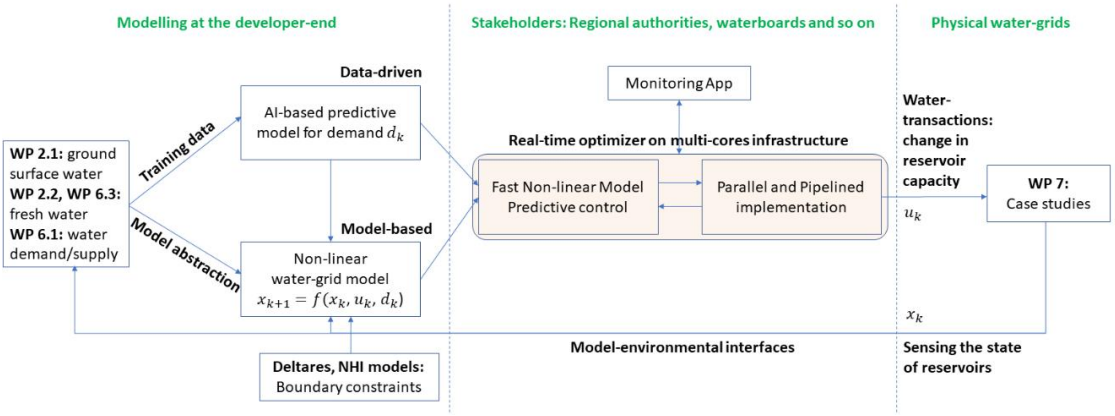

Figure 7. Overview of the Water Embedded Model Predictive Control (WE-MPC) framework

This is an advancement of classical solutions for optimal control of water grids (e.g., www.deltares.nl/en/software), which use a supervisory centralized control architecture. We will abstract scalable physical water grid models (to deal with different time scales) from regional and large-scale models to be developed in WPs 2.1-2.2 in order to obtain realistic models of representative water grids under consideration in the case studies in WP7. An Artificial Intelligence-based predictive model for future water demand in local smart water grids will also be developed and integrated within the water network physical model. The combined water grid model has to satisfy boundary conditions, e.g., scarcity, imposed by regional and national NHI models, co-developed by Deltares. The WE-MPC framework will run on a backend server with multi-core processing infrastructure (hosted by the stakeholders). A monitoring app for phones/Tablets will be developed for allowing for human intervention and monitoring. The WE-MPC framework will enable the AquaConnect stakeholders to adjust their planning continuously to meet local water demands and boundary constraints.

Connection to other work packages. WP 2.1-2.2, WP 6.1 and WP 6.3 will develop regional and large-scale predictive models for groundwater, fresh water infrastructure and water demand/supply. This work package will use data and structure of these models to abstract the scalable MPC-compliance non-linear model shown in Fig. y. To increase data reliability, high-fidelity models (such as KWR SIMDEUM) and data from the case-studies Zuid-Holland and Zeeuws-Vlaanderen (WP7) will be used. Integration with the tools for predictive management of fresh water reserves to be developed in WP 2.2 will be investigated. The WE-MPC framework will also contribute to the economical and societal aspects to be dealt with in WP 5 by enabling faster balancing of supply and demand in local smart water grids.

Time plan and division of tasks

Activity ↓ Months →	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Design of nonlinear water grids models for predictive control								
2. Develop fast optimization solvers for nonlinear MPC.								
3. Develop an accurate and scalable AI-based predictive model of future water demand integrable in the WE-MPC framework								
4. Integration with the large-scale data-driven models to be developed in WPs 2.1-2.2, WP 6.1, WP 6.3								
5. Efficient implementation of nonlinear MPC								
6. Prototype validation of the WE-MPC framework in at least two case studies								
7. Real-time water-grid monitoring app								
8. Manuscript and thesis writing								

Methods We will develop realistic nonlinear models of water grids abstracted from physical modelling and using very recent data-driven identification methods for physical networks[5]. Further, data-driven supervised machine learning techniques will be used to construct intelligent predictive models of water demand compatible with models used by nonlinear MPC. Efficient nonlinear MPC solvers will be developed using parallelizable branch and bound solvers[6], parallelizable nonlinear MPC designs[7] and efficient warm start methods. For real-time embedded implementation of the above MPC, we will research methods for co-design of numerical solvers and multi-core computing hardware[8], as recently initiated by one of the co-applicants. Fast real-time solvers for nonlinear MPC will be developed by co-design of fast optimization routines and efficient memory allocation (required for data sharing), communication (required for data exchange) and computation (over multiple cores in parallel or pipelined) architectures[9]. Adaptation is required to

achieve compatibility with existing processing infrastructures in water-grid control schemes[1]. The company ICT Netherlands B.V. (ICT-NL) will provide technical expertise for addressing this challenge. The developed software will be tested in the Robust Water System Zeeuws-Vlaanderen and other available studies.

Contribution to AquaConnect deliverables The proposed WE-MPC framework directly contributes to AquaConnect ambition of digital technologies for dynamic monitoring, peer-to-peer (producer-to-consumer) water supply and demand and social inclusive water resource management towards achieving climate-robust water cycles. The WP 6.2 provides insight into feasibility, implementation and effectiveness of the real-time monitoring and closed-loop control of future smart water grids considering the case-studies. This WP contributes to the different AquaConnect deliverables as explained next. *Case-specific problem analysis*: The case-study specific data-driven models of groundwater, fresh and surface water infrastructure from WP 2.1-2.2 will be used for abstracting MPC specific scalable and realistic models. This will provide case-study specific water grid models for MPC (deliverable 1). These models will be used in the WE-MPC toolbox contributing to the digital technology of ambition of AquaConnect (deliverable 2). The WE-MPC framework will be validated in one or more case studies (deliverable 4). *Key-technologies*: Development of a real-time monitoring and model predictive control toolbox for smart water-grids. *Governance instruments*: The output of this WP functions as input to the water authorities, drinking water companies, and water users to consider real-time water-transactions for efficient water resource management. *Integrated case-specific solutions*: The case-study specific models will be integrated for the validation of WE-MPC framework (deliverable 1 and 4).

Role of users This project is executed by the PhD and PD (under the supervision of (co-)applicants). ICT-NL has extensive experience in water industry software and will support the development of the real-time multi-core implementation and monitoring app (deliverable 2). Deltares will provide knowledge, existing data or models on the connection between this research and tools such as RTC, NHI models, to develop case-study specific models (deliverable 1).

Intellectual property All results will be in principle open access for the full consortium (IP domain I). There are no limiting contracts or agreements with third parties. Cited state-of-the-art methods are published and open for usage.

WP. 6.3. Redesign of Higher Sandy Regions towards improved fresh water availability
Project leader: Prof. Dr. Ir. Sjoerd E.A.T.M. van der Zee, Wageningen University
Co-applicant(s): Dr. Perry de Louw (Deltares), Dr. Ir. Ruud Bartholomeus (KWR-Water)
Requested research positions: 1 PhD; **Duration of project**: 4.5 years

Scientific description of the work package

The higher sandy regions are increasingly confronted with drought in agriculture and nature, due to discrepancy between precipitation and evapotranspiration demand, and interventions in the past to remove excess water preventing flooding, use of groundwater for drinking, industry and agriculture and reduced groundwater recharge due to land use changes (e.g., pine forests planting). sandy regions with a mosaic of intertwined functions with conflicting water requirements (mainly nature, agriculture, drinking water companies) oppose to optimize for all functions. In this WP, we develop an instrument with three purposes: (i) provide a methodology for redesign the landscape and water system and (ii) enable and quantify the integrated dimensioning of such a redesign including innovative measures, (iii) optimize this redesign. To improve water availability yet avoid periodic flooding or water quality issues, we must be able to perform fast simulations of real regions to assess impacts and optimize a diversity of integrated measures. Experiences illustrated that a new design comprises local changes and innovations as underground storage of effluent, drainage of river water, besides landscape scale measures of regional planning, changes in land use and infrastructure.

Scientific challenges

The challenge is to jointly address the regional structure of rural areas, but particularly of the hydrological organization (shallow surface water system; deeper geohydrological system). These building blocks of the environment affect each other with many cross-relations and feedbacks, and a spatial coherence of the water system. Interventions in part of this environment influence all other parts of it, though with different impact. Despite this awareness, an integrated quantitative tool is lacking. Partial tools at national scale (NHI)[1] and regional scale (e.g. MIPWA[2], AZURE[3]) are available, but too exclusive for the assessment of measures and their effectivity, because measures change the (infrastructural and landscape) system as well as the hydrological system itself. Hence, the organization and parameterization of the regional (High Sandy Regions) NHI, MIPWA, or AZURE implementation will change. Intrinsic to this WP, feedbacks and iterations concern the landscape structure and the hydrological system, but also the need to iterate local and regional interventions and integrated effects, e.g. between the different scales, as local (e.g. village, nature, wetland, and farm requirements) and regional interests (water retention and removal) need to be served and conflicts of interests resolved. Fast simulation tools to quantify effects (water table, groundwater seepage, base & peak flow, ground & surface water quality) relevant for all water users need to be operated in an integrated way.

Time Plan and Division of Tasks

Activity ↓ Months →	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
1. Select two study areas at catchment scale in south and east parts of the Sandy Soils where the constructed method and tools will be applied, in close collaboration of stakeholders. Collect (geo)hydrological data, align models (regional surface & groundwater).								
2. Develop a method for redesign of the sandy landscape and water system optimization								
3. Construct fast calculating toolbox which quantify integrated effects based on existing deterministic models, via impulse-response, meta-relations or smart modeling techniques.								
4. Apply developed method and tools for the two catchment areas.								
5. Writing papers and PhD thesis.								

Methods

In the Higher Sandy Area, two demonstration regions (south and east) will be selected with the involved stakeholders. Available data bases of present infrastructure, land use, (*geo*)hydrology, and cross-boundary influences (e.g. incoming/outgoing water, produce) is inventoried, using locally implemented groundwater models, tools, data, and insights of regional authorities, such as water authorities, provinces, nature conservation and agricultural organisations. This way, a digital twin can be constructed of the regions. For computation, an objective procedure to iterate between local and regional cause-effect relations is developed. Typically, the system itself changes by interventions (related with nature targets, distribution and patchiness of land use, target yields or crop, EU Water Framework Directive, WB21...) and external factors as global change. So local models change and inspiration is needed how small differences in local conditions are related to different responses. Thus, the continuum in time of moving from one state to another is connected to current ground truth at different locations. Besides water quantity, also water quality is addressed, which involves straightforward changes, as introducing water with different chemical signature into nature reserves, re-use of treated effluent in agriculture, transformations of groundwater composition but also indirect consequences. Aim of this WP is to provide a scientific tool for integrated assessments by which stakeholders can determine the impacts of intended interventions. The focus is evaluate how profound and regional scale changes affect the system and its responses, including the target of improving fresh water availability at times where needed. Thus, river water that is re-directed during winter and spring towards the higher areas for infiltration will be one of the interventions to be studied, besides the upscaling of re-use of treated effluents in agriculture. In combination with WP4, socio-economic and governance issues are brought into consideration.

Contribution to program

This WP integrates digital tools developed in WPs 2.1, 2.2, 6.2 and 6.3, plus tools developed in the context of this WP, into an instrument for regional planning and design, with a focus on the hydrological behaviour and integrity of the system. The deliverables of this WP are innovative, focused on practical implementation and use by a large group of stakeholders at a regional scale. The generic parts of the WP are readily applicable to other regions of the sandy area.

Contribution to AquaConnect deliverables

This WPs provides the necessary tools (deliverable C) for the redesign of the Higher Sandy regions (deliverable D), which contributes to the identification of problems with current regional water management (deliverable A) and leads to successful demonstration of new key technologies in the region (deliverable E).

Role of users

Provinces and water authorities have the difficult task to optimize the water system to reconcile wishes of water users and meet national/ EU rules as NATURE2000 and EU Water Framework Directive. Redesign of the land and water system requires the involvement of all stakeholders (agriculture, nature conservation, drinking water companies, industry) and an objective method and quantitative tools to support this process. The need of such a support system is confirmed by the stakeholders and their involvement in AQUACONNECT (Province of North-Brabant, water authorities 'Vallei en Veluwe', 'Vechtstromen', 'Rijn and Ijssel', 'Aa en Maas' and drinking water companies Vitens and Brabant Water). Stakeholders will be intensively involved in the application of the method and tools in one of the two study areas, providing data, tools, information and ideas.

Intellectual property

All results will be in principle open access for the full consortium (IP domain I).

5.2.6 Work package 7: Case-study demonstration and (inter)national outreach.

WP7A. Demonstration in case study regions, upscaling and international outreach: 7.1. Zeeuws-Vlaanderen, 7.2. South-Holland, 7.3. Metropolitan Region Amsterdam, 7.4. Higher Sandy Soils, 7.5. International Cases; 7.6. Integrating smart water-grid solutions for upscaling in NL
Project leader: Prof. dr. Huub Rijnaarts (WUR) in collaboration with Paul Roeleveld RH DHV and Arjen van Nieuwenhuijzen Witteveen and Bos/AMS **Co-applicant(s):** HZ-UaS, Deltares, KWR, WEnR, AMS, WI & BOS, RHDHV, STOWA, All case related to in kind co-financing partners; Contributions of all academic and institutional partners **Requested research positions:** 40 % WUR Management AC plus 40% in kind input of RHDHV and WI&BOS; in kind contributions of co-financing partners; 10% of time of all PhD researchers and 25% of time of all postdoc researchers participating in AquaConnect. **Duration of project**: 4.5 years

Demonstration of the key technologies developed in AquaConnect in the case-study regions (Zeeuws-Vlaanderen, South-Holland, Higher Sandy Regions and Amsterdam Metropole Region) is an essential step within the process from scientific knowledge development to full market application, i.e. the pathway of impact of AquaConnect. The translation of the scientific outcomes of AquaConnect to scalable solutions applied in the case-study regions is performed by the research institutes that are already active in the region in ongoing research programs and that have close connections with the regional stakeholders. They will take a leading role in translating the scientific knowledge obtained in AquaConnect to region-specific solutions. The foreseen activities are outlined below:

Case study regions	**Zeeuws-Vlaanderen (WP 7.1)**	**South-Holland (WP 7.2)**	**Higher Sandy Soils Regions (WP 7.3)**	**Amsterdam Metropolitan Region (WP 7.4)**
Responsible research institute	HZ University of Applied Sciences	Deltares	KWR | WEnR	AMS Institute
Case-study manager(s)	Hans Cappon	Esther van Baaren; Hans van Duijne; Klaasjan Raat	Ruud Bartholomeus/ Koen Wetser; Paul Roeleveld	Arjen van Nieuwenhuijzen; Willie van den Broek
Regional Stakeholders contributing in kind	Province of Zeeland Municipality Terneuzen Evides WB Scheldestromen DOW Benelux North Sea Port	Province of South-Holland Evides, Dunea, Oasen Port of Rotterdam, GlastuinbouwNL	Province of North-Brabant, Vitens, Brabant Water, water authorities (Rijn & Ijssel, Vallei & Veluwe, Vechtstromen, Aa en Maas), Swinkels Brewerey	AMS, Municipality Amsterdam Hoogheemraadschap Holland Noorderkwartier PWN
WORKSHOP and other actions for each study region	Workshops with regional stakeholders will be organised to i) clearly define expected output from scientific Aquaconnect workpackages as input for regional water provision problems and mutually communicate the AquaConnect vision of success; ii) Connect AquaConnect researchers with ongoing pilots in the case-study regions, iii) Guide stakeholders to implementation of key technologies and governance instruments developed in AquaConnect, iv) translate the output of scientific workpackages to integrated region-specific solutions for fresh water provision problems in the form of smart water-grids, v) Identify potential new locations for demonstration of AquaConnect water-grids in the region. Some of these workshops will be shared with two or more regions when convenient			
Region-specific activities by research institutes				
Connecting AquaConnect to current research initiatives in the region	E4Water[1], IMPROVED[2] FRESH4Cs[3], Water Nexus[4]; TKI Wetlands HZU01[5], TKIEffluent4Use; Cross border collaborations Flanders/VLAKWA	COASTAR[6]	Lumbricus[7] KLIMAP[8] TKI "Zicht op elke Drup" Water in the Circular Economy (WiCE)[9]	SaltiSolutions EU project RainSolutions[10]

Connecting to new and ongoing pilots				
	PILOT Dow Benelux Water Reuse and CW Storage Scaled up Pilots	**PILOT** Dunea brackish water treatment and re-infiltration in Dune area	**PILOTs** WaterFabriek (WILP) and others for circular and subsurface stored water	**PILOT** NEW HEART Wervershoof, for circular and resource oriented water treatment and water provision
Specific contribution to workpackages to facilitate pathway from output to outcome				
PROVIDE:	water quality/quantity requirements of regional water users to WPs 2, 3, 4 and 6; suitable locations for testing newly developed technologies in WP4 in cooperation with regional stakeholders; WP5 with ongoing research at HZ on fresh water economics in collaboration with the province and municipality	Co-supervision (Deltares) of PhDs in WPs 2.1&2 on groundwater modelling and input on model development WPs 6.1&2&3; Knowledge exchange with on freshwater governance (WP5); exchange with WP3,4 of risks for brines and sludges and treatment technologies	Integration of scientific insights of the technological WPs 2, 3, 4 and 6 to the social context of WP5; support in economic evaluation and water valuation and use of new technologies developed smart water grid landscape in HSS	Data and access to running pilots in Wervershoof and dune infiltration PWN for WPs 3, 4, 5 and 6; Data on A'dam green infra (parks) for alter-native irrigation **SWG4a** connecting water supply for industry and dune infiltration demo around PILOT Wervershoof/New Heart waste water treatment facility and PWN dune infiltration PILOT
CO-CREATE: Design of Smart Water Grid (SWG) Together with WP6 (see Fig 7.1.)	**SWG1** Connecting water supply for industry, nature and agriculture in Zeeuws Vlaanderen including cross border water imports and exports with Belgium Flanders	**SWG2** Connecting water supply for industry (port of Rotterdam), horticulture and Dune infiltration based on recycling and brackish water treatment in South Holland	**SWG3** connecting water supply based on nature based water holding capacity in subsurface and reuse of effluents for Higher Sandy Soils	**SWG4b** for alternative water sources for irrigating Amsterdam Parks during dry summers
WP 7.5: Inclusion of international cases: lessons learned and knowledge exchange				
International Collaborations	**Vietnam** Management of three industrial parks in HCMC adopting circular water NWO-UDW ENTIRE project (WUR)	**Chili** Qoquimbo area artificial recharge of aquifers to capture spring meltwaters and effluents to sustain dry season agriculture (Deltares)	**Qatar** Greening the dessert program reusing GTL and Doha city effluents (Shell)	**Bangladesh** Khulna City region; Urban water grid supporting irrigative agriculture; Nuffic project Water2RICE ends 2021 (WUR)
WP 7.6: Integrating smart water-grid solutions for upscaling in NL				
Under the lead of RH DHV and WI & BOS and management of AC (WUR), all generated insights and results of WP 7.1-5 will be brought together in Smart Grid Design workshops, to be held at the start of AquaConnect, the end of the first, the second and third year. In the final year these results will be compiled to an alternative water provision approach, including governance innovations, and technologies and smart grid infrastructures needed (including those developed in AquaConnect). Thus, a knowledge and technology package will be created for communicating how to use alternative water resources, create and operate smart water grids, and how these can be upscaled to full implementation in the Netherlands. STOWA, Water Boards, Drinking water companies, UvW, Water Alliance, Min I&W, Provinces, Port organisations, and industries will test the approach as end users.				

Figure 7.1 Example of a smart water grid design for the region Zeeuws Vlaanderen, with the aim to come with similar but more **extended designs for all four case study regions**. In this figure one industrial end user (Red dot) is connected (colored lines) to multiple sources of brackish and fresh water effluents covering a water provision of 5.5 million m3 per year. For all four case regions, such smart grids will be designed for connecting specific demands and supply.

WP7B. Demonstration in case study regions, upscaling and international outreach

Project leader: Hans van Duijne (Deltares) and Dr. Katarzyna Kujawa (WUR)
in collaboration with Paul Roeleveld RH DHV, Arjen van Nieuwenhuijzen Witteveen and Bos/AMS, and under end responsibility of Huub Rijnaarts (WUR)
Co-applicant(s): WI & BOS, RH DHV, UvW, Water Alliance, partners in BLUEDEAL (waterboards and drinking water companies), Shell Netherlands, Several Embassies (Chili, Vietnam, Bangladesh, Middle East and others); Academic and institutional partners interested
Requested research positions: 10% of in kind input of RH DHV and WI and BOS; 10 % Management AC plus in kind contributions of interested co-financing partners; 10% of input of Deltares; In kind input of Shell; BLUEDEAL program inputs through water boards and drinking water companies.
Duration of project: 4.5 years

Background. International outreach of AquaConnect will be essential to make an impact at a global level. On the one hand, the program will adopt knowledge-business-governance approaches to disseminate the generated knowledge into international connections with governments, universities and business opportunities for Dutch companies. On the other hand, the cases abroad can be used as example for the Dutch setting. The foreign cases have, in aspects, more extreme boundary conditions and therefore we can learn from those cases. Through existing and new relations with international partners and end-users involved, we will ensure the sound governance arrangement in the program. Dutch Embassies in the international outreach countries will play a pivotal role in identifying users and facilitating discussion to pave the route to impact on mitigating the effect of water scarcity.
Dissemination platform from AquaConnect international twinning. Being delta countries, Chile, Middle East, Vietnam and Bangladesh, face severe freshwater shortages for agricultural as well as industrial activities. Climate change and rapid urbanization are pressuring on the available water resources; thus, circular water use can be useful in coping with the negative impact of climate change. In Chile, Vietnam and Bangladesh basin management plans and implementation projetcs have been formulated with the support of the Dutch government with ample opportunities for the Dutch private sector.. The NWO funded ENTIRE project in Vietnam has identified the urban water reuse potential in the industrial zones of Ho-Chi-Minh city. In Chile the GIRAgua project is being implemented through the Partners for Water Program and in Qatar Shell want to set up a water management plan connected to their plant. All these available knowledges can be further investigated through AquaConnect.
Further development of industries, technology-providers, consultancies and Water Boards/Drinking water Companies. Partnering with different governmental, university, industrial and consultancy companies from the Netherlands, AquaConnect will investigate the possibility of reuse effluents and recharge of aquifers. An integrated climate-robust water system combining new potential water sources (WP2), associated risk assessment (WP3) and new technology for pollutant removal (WP4) will be crucial in upgrading the wastewater and sludge quality making it safe for agricultural as well for other applications. The digital technology development (WP 2 and 6) is a useful for the cases abroad. This approach can be used around the globe in the focus countries where industries, technology providers or BLUEDEAL partners can be involved aiming to provide technological solutions to make surface water, wastewater or sludge reusable, including consultancy companies to advocate such concepts in global markets.
Planning WP7 A and B, in the creation of deliverables A-F (Figure 2), in conjunction with WP 2-6

Activity ↓ ***Months →***	*6*	*12*	*18*	*24*	*30*	*36*	*42*	*48*
Deliverables A (Fig. 2, problem analyses)								
Deliverables B and C (Fig. 2, Governance tools, technologies)								
Deliverables D, E and F (Fig. 2, scalable smart grids, upscaling, outreach)								

6 Annexes

6.1 References

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Section 5

5.2.2

WP2.1. Regional high-resolution integrated groundwater-surface water modelling

WP2.2. Management of fresh groundwater resources using data-model integration

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WP3.2. Improving prediction of micropollutant transformation product formation in groundwater systems.

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WP5.2. Legal- and policy assessment for circular water governance

WP5.3. Science-policy interaction, stakeholder involvement and upscaling

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Section 5.2.6

WP6.1. Robust optimisation of future smart water grids at scale: harnessing heterogeneity of supply and demand through centralised and decentralised decision systems

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WP6.2. Real-time monitoring and model predictive control of smart water-grids

1. G. Cembrano, G. Wells, J. Quevedo, R. Perez, R. Argelaguet, 2000. Optimal control of a water distribution network in a supervisor control system, Control Engineering Practice, Vol. 8, pp. 1177 – 1188.
2. M. K. Singh, V. Kekatos, 2019. Optimal Scheduling of Water Distribution Systems, in IEEE Transactions on Control of Network Systems, published on-line, doi: 10.1109/TCNS.2019.2939651.
3. P.J. van Overloop, R.R. Negenborn, B. De Schutter, N.C. van de Giessen, 2010. Predictive control for national water flow optimization in the Netherlands, Intelligent Infrastructures, Eds. Negenborn, Lukszo and Hellendoorn, Springer series Intelligent Systems, Control and Automation: Science and Engineering, pp. 439 – 461.
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5. E.M.M. Kivits, P.M.J Van den Hof, 2019. A dynamic network approach to identification of physical systems, IEEE Conference on Decision and Control, Nice, France.
6. J.F.R. Herrera, J.M.G. Sarmeron, E.M.T. Hendrix, R. Asenjo, L.G. Casado, 2017. On parallel branch and bound frameworks for global optimization, Journal of Global Optimization, Vol. 69, pp. 547 – 560.
7. R.V. Bobiti, M. Lazar, 2017. Toward parallelizable sampling-based nonlinear model predictive control, Proc. of the 20th IFAC World Congress, IFAC PapersOnLine, Vol. 50 (1), pp. 13176 – 13181.
8. A. Ibrahim, I. M. Soroa, H. Li, D. Goswami, A.A. (Twan) Basten, 2020. Performance Analysis of Embedded Platoon Controllers, IEEE Vehicular Technology Conference, Antwerp, Belgium.
9. S. Mohamed, D. Goswami, V. Nathan, R. Rajappa, A.A. (Twan) Basten, 2020. A scenario- and platform-aware design flow for image-based control systems, Microprocessors and Microsystems, Vol. 57.

WP6.3. Redesign of Higher Sandy Regions towards improved fresh water availability

1. http://www.nhi.nu/nl/index.php/data/
2. https://oss.deltares.nl/nl/web/imod/mipwa-showcase
3. https://www.waterforum.net/nieuw-grondwatermodel-azure-levert-gedetailleerde-hydrologische-informatie/

WP7. Case-study demonstration and (inter)national outreach

1. www.e4water.eu
2. www.improvedwater.eu
3. www.fresh4cs.eu
4. www.waternexus.nl
5. www.tkideltatechnologie.nl/project/hzu01-wetlands-als-voorzuivering-voor-milde-ontzilting
6. www.coastar.nl
7. www.programmalumbricus.nl
8. https://www.waterforum.net/klimap-project-naar-een-regionale-uitrol-klimaatadaptieve-maatregelen-voor-hooggelegen-zandgronden/
9. https://www.kwrwater.nl/en/samenwerkingen/collectief-onderzoek-water-circulaire-economie/
10. https://www.rainsolutions.info/

6.2 Abbreviations and acronyms

AC – AquaConnect
CEC – Contaminant of Emerging Concern
WP – Work Package
NHI – Nederlands Hydrologisch Instrumentarium

AMS – Amsterdam Metropolitan Solutions
HHNK – Hoogheemraadschap Hollands Noorderkwartier
NWP – Netherlands Water Partnership
Wi-BO – Witteveen & Bos
RHDHV – Royal Haskoning DHV

WUR – Wageningen University & Research
UvA – University of Amsterdam
VU – Vrije Universiteit
TU/D – Technical University Delft
TU/E – Technical University Eindhoven
UT – University of Twente
UU – University of Utrecht
HZ – Hogeschool Zeeland, University of Applied Sciences
WEnR – Wageningen Environmental Research

6.3 Overview Budget program

Include here a pdf of the "Overview program" from the budget form (Excel)

This is an overview of the programme. Just add the programme number and title.

Annex 6.3

PHASE 3 **Programme proposals**

Program: P19-45
Title: AquaConnect

								Co-financing							Part of Total expenditures	
Project/Work package	Main applicant	Personnel (5)	Material*	Investments*	Knowledge utilisation*	Inter-nationalisation & Money follows Cooperation*	Total expenditures	In cash cofinancing	% in cash cofinancing	In kind cofinancing	Total cofinancing	% total cofinancing (4)	NWO contribution	Total program costs	Expenditures TO2 institutes	Expenditures Universities of applied sciences
P19-45 AquaConnect | Key technologies for saf	Prof. dr. Huub Rijnaarts	€ 4,358,580	€ 716,000	€ 127,000	€ 25,000	€ 25,000	€ 5,251,580	€ 840,000	16.00%	€ 649,865	€ 1,489,865	25.25%	€ 4,411,580	€ 5,901,445	€ 300,010	€ 200,070
		€ -	€ -	€ -	€ -	€ -	€ -	€ 578,750	-	€ 346,515	€ 925,265	267.02%	€ -578,750	€ 346,515	€ -	€ -
		€ -	€ -	€ -	€ -	€ -	€ -	€ -	-	€ -	€ -	-	€ -	€ -	€ -	€ -
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		€ -	€ -	€ -	€ -	€ -	€ -	€ -	-	€ -	€ -	-	€ -	€ -	€ -	€ -
TOTAL projects (incl VAT)		**€ 4,358,580**	**€ 716,000**	**€ 127,000**	**€ 25,000**	**€ 25,000**	**€ 5,251,580**	**€ 1,418,750**	**27.02%**	**€ 996,380**	**€ 2,415,130**	38.65%	**€ 3,832,830**	**€ 6,247,960**	**€ 300,010**	**€ 200,070**
Project Governance	Prof. dr. Huub Rijnaarts	€ 132,141	€ 35,000	€ -	€ -	€ -	€ 167,141	€ -	0.00%	€ -	€ -	0.00%	€ 167,141	€ 167,141	€ -	€ -
TOTAL programme cost		**€ 4,490,721**	**€ 751,000**	**€ 127,000**	**€ 25,000**	**€ 25,000**	**€ 5,418,721**	**€ 1,418,750**	26.18%	**€ 996,380**	**€ 2,415,130**	37.65%	**€ 3,999,971.2**	**€ 6,415,101**	**€ 300,010**	**€ 200,070**

Summary expenditures		
Expenditures universities/UMC/NWO-i/etc.	€ 4,918,641.20	91%
Expenditures TO2 instututes	€ 300,010.00	6%
Expenditures Universities of applied sciences	€ 200,070.00	4%
Total	€ 5,418,721.20	100%

Check: NWO contribution program activities/ funding requested from NWO for the entire program: 4.18%

6.4 Letters of support

We received 37 letters of support from the following users:

Companies		
Royal Haskoning DHV	Vitens	Dow Benelux
Witteveen&Bos	Oasen	Shell
Nijhuis Industrial Technologies	Dunea	Swinkels
ICT Netherlands B.V.	Brabant Water	Stibbe
Evides	KnowH_2O	NXFiltration

Knowledge institutes	
KWR Water Research Institute	AMS Institute

Other organisations		
Ministry of Infrastructure and Water Management	Water authority Vallei & Veluwe	STOWA
Province of South-Holland	Water authority Rijn & IJssel	North Sea Port
Province of Zeeland	Water authority Vechtstromen	GlastuinbouwNL
Province of North-Brabant	Water authority Scheldestromen	Water Alliance
Municipality of Terneuzen	Water authority Hoogheemraadschap Holland Noorderkwartier	Port of Rotterdam
Municipality of Amsterdam	Water authority Aa en Maas	Netherlands Water Partnership

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ADVANCED METROPOLITAN SOLUTIONS

Dr.ir. Huub Rijnaarts
Wageningen University & Research (WUR)
Environmental Technology Group (ETE)
P.O. Box 17
6700 AA Wageningen

Subject: Letter of Support to 'NWO TTW Perspectief – P19-45 AquaConnect"

Amsterdam, July 17th 2020

Dear Huub Rijnaarts,

With this letter I declare on behalf of Amsterdam Institute of Advanced Metropolitan Solutions (AMS) our interest in and support for your research proposal "AquaConnect" for the NWO-TTW-Perspectief tender.

As AMS, we have taken notice of the conditions for the NWO-TTW-Perspectief call and have been informed about your application in this call. We are very interested in participating in this research programme, focussing on the Demo Fresh Water Challenges Amsterdam Metropolitan Area and North-Holland.

AMS Institute works on finding interdisciplinary metropolitan solutions. We are a public institute with 32 employees, consisting of mainly programme developers, principal investigators, research fellows, etc. In close collaboration with both public & private partners and citizens, we valorise our research in practice, using the city of Amsterdam as a living lab. In all our research and education activities we work closely together with a broad network of industry, governmental and societal partners to initiate revolutions in new technologies, research and design methods.

Circularity is one of the main themes within AMS research programme. As a circular water demo case study, the urbanized North Holland Coastal zone of the Amsterdam Metropolitan Area is affected more and more by climate change related salty and brackish water intrusion in to surface water and ground water bodies. Hereby ecological fresh water values and water sources for urban water supply are endangered. The salt pressure to the North Sea Channel and the coastal water systems increase severely due to increasing sea water levels and men-made structures like the upgrading and extension of the IJmuiden Ship Locks at the seaport 21 kilometers west of Amsterdam. Each time the locks at IJmuiden open, seawater flows into the Noordzeekanaal (North Sea Channel). In the future the locks will be even larger after reconstruction and will discharge salty water in larger flows. The salty water mixes with the sweet water of the Amstel delta and the IJsselmeer, and the brackish water eventually reaches the canals of Amsterdam. Waternet determined

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ADVANCED METROPOLITAN SOLUTIONS

the levels of salt and oxygen in the water of the canals and the Amstel and IJ river. In the IJ one liter of water contains about 5.000 milligrams of salt about 1/3 of the salt content of the North Sea. By keeping fresh water, storm water and upcycled used water in the water system, the brackish water challenge can be solved. This accounts to cleaned fresh water discharge from (large) used water treatment plants like Haarlem, Beverwijk, Zaandam, Amsterdam-West, Amstelveen into the MRA water system as well as for storm water.

Within metropolitan areas and regional communities, potable water production facilities are also challenged by more and more brackish feed water from subsoil or surface water. PWN and Waterboard HHNK are already developing even more innovative closed water systems with a smart combination of chemical-physical treatment and nature based solutions to create circular water solutions. The future water system in Amsterdam will develop significantly by these approaches.
The Amsterdam Metropolitan Area with its stakeholders like the Province of Noord-Holland, Waternet and Water Authority of Hollands Noorderkwartier as well as the City of Amsterdam and the municipalities of Velsen, Beverwijk and Zaandam, are directly affected by the upcoming fresh water availability challenges.

For AMS Institute, we foresee participation in AquaConnect as setting a base for a large program connecting the Circular, Energy and Food programme into a new integrated program. For the near future, with the rise of the electrification of sustainable processes, water will be demanded and used by energy providers (cooling, H_2-energy) and sustainable industry users and therefore the water grid will become connected to the electrical grid. The new food programme of the city of Amsterdam will focus in particular on local food production and urban green, which demands and uses water with high quality in extreme conditions (droughts, high temperatures and the earlier mentioned salinization of surface and ground water). There is a need to anticipate on these upcoming trends and this AquaConnect program allows to setup and create a knowledge & innovation platform and organises the required expertise to create innovations for the near future.

Item or activity	*(Cost-)price or rate*	*Amount*
Data and information collection and provision regarding practical challenges and the demand from researchers and designers for de Demo	€103,- per person per hour	80
Participation of workshops for the tool improvement and	€103,- per person per hour	64 (for the PhD duration)

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application related to the Demo		
Total estimated value		€14,832

We will provide an ***in-cash* contribution** of 75,000. euros, inclusive of Dutch VAT and an ***in-kind contribution*** of 14,832 euros. This amount and, if applicable, the required additional Dutch VAT will be paid to NWO if the application is granted.

We will support the project with an ***in-kind contribution*** as itemised in the table above. Within the Demo MRA, research into integrated mitigation measures by applying nature based and technical (chemical) solutions to solve the brackish water intrusion and effects will be carried out for the MRA case. Research activities will be related to the abovementioned developments and focus specifically on circular water technologies and removal of emerging substances as well as the connection to social, legal and organizational acceptance and participation for closed water solutions in the MRA.

Furthermore, we state that we will actively participate in the project committee established after award of the project and that we will comply with the applicable terms and conditions for participation.

We are aware of the NWO Grant Rules and obligatory establishment of a project agreement containing, amongst other issues, IP arrangements and as consortium partner we will share responsibility for a prompt completion of the project agreement.

Yours sincerely,

Kenneth Heijns
Managing Director
AMS Institute

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Waterschap Aa en Maas
Pettelaarpark 70
5216 PP 's-Hertogenbosch

September 3rd , 2020

Dear professor Rijnaarts,

Water board Aa en Maas (WAM) is a regional governmental organization of appr. 400 employees that operates in the Southern part of the Netherlands. WAM is responsible for the complete water management in the region and has a yearly turnover of appr. 100 million euro/yr. The main tasks are waste water treatment, water level management for agriculture and management and maintenance of the dikes. Because of these responsibilities, the aim of this project is highly relevant to us. In addition to our daily work for drought control, we recently started the initiative of The Water Factory, together with the Energy and Resource Factory (www.efgf.nl/english). An ambition, and a technological concept, for reusing the treated waste water from our wwtps for industries and agriculture. A complex process, as we seem to run into different kinds of obstacles like water quality, safety- and governance issues. We expect that AQUACONNECT will help us solve these issues, or at least provide us with more insights on these topics. We also expect that it will raise awareness on the urgency of water reuse in our region.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. Waterschap Aa en Maas acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 9,340 and an in-cash contribution of € 20,000. The in-kind contribution consists of:

A. Further defining the scientific research questions in the first phase of Aquaconnect in collaboration with the AquaConnect PhD-researchers;
B. Connecting the AquaConnect research with existing pilots, such as the initiatives of The Water Factory
C. Identifying suitable locations for future demonstrations of AquaConnect smart water-grids
D. Facilitating the connection between the wwtps and the surface waters

Description	Hours	€/hour	Total (€)
Innovator	*30*	*103*	*3.090*
Waste water technologist	*30*	*71*	*2.130*
Policymaker / account manager	*30*	*103*	*3.090*
Manager water chain	*10*	*103*	*1.030*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,

Ferdinand Kiestra
Innovation manager waterschap Aa en Maas
Member of the National program team 'Energy and Resource Factory'
Chairman of the working group Water Factory

From: Haan, ER, de <er.de.haan@pzh.nl>
Sent: dinsdag 1 september 2020 09:39
To: Stekelenburg, A. [Anke] <a.stekelenburg@NWO.NL>; Jonge, B. de [Bastiaan] <b.dejonge@nwo.nl>
Cc: Rijnaarts, Huub <huub.rijnaarts@wur.nl>; Hans van Duijne <Hans.vanDuijne@deltares.nl>; Wagner, Thomas <thomas.wagner@wur.nl>; Esther van Baaren <Esther.vanBaaren@deltares.nl>; Westerhof T.B.M. (Thecla) <tbm.westerhof@zeeland.nl>
Subject: Besluitvormingsprocedure Aquaconnect provincie Zuid-Holland

Beste Anke,

Gisteren heb ik in het portefeuillehoudersoverleg de Letter of Support voor het projectvoorstel Aquaconnect besproken met de verantwoordelijk gedeputeerde Jeannette Baljeu. Jeannette is akkoord met provinciale deelname aan Aquaconnect door middel van de vast te stellen Letter of Support. Het voorstel wordt nu geagendeerd in het College van GS van 15 september. Financiële dekking voor de in de Letter of Support voorgestelde bijdrage van € 75.000,- wordt verkregen uit bestaande middelen op de begroting. Hetzelfde geldt voor de in de Letter opgenomen uren, deze worden gedekt uit de bestaande vaste formatie binnen de afdeling Water en Groen. M.a.w. de dekking is geen probleem. De financiële bijdrage zal t.z.t. door middel van een incidentele of begrotingssubsidie worden verstrekt. Zoals eerder aangegeven is dat een bevoegdheid van provinciale staten, waar niet van kan worden afgeweken (bepalingen in de Algemene Subsidie Verordening Zuid-Holland).

Intern provincie zet ik nu de formele besluitvormingsprocedure in gang. Deze verloopt via een zogenaamde workflow met advisering van de afdeling financiële en juridische zaken. Deze collega's weten van het voorstel en zijn ook in de voorfase al betrokken.

Na vaststelling van de brief op 15 september wordt deze z.s.m. ondertekend door de Commissaris van de Koning en de provinciesecretaris. De (gescande) brief zal ik daarna meteen mailen naar NWO in afschrift aan het consortium.

Met vriendelijke groet,

Erik de Haan
Provincie Zuid-Holland
Afdeling Water en Groen
M. 06-55449453

From: Beveren, Patrick van <P.van.Beveren@amsterdam.nl>
Sent: donderdag 3 september 2020 17:26
To: Annemarie van Wezel <a.p.vanwezel@uva.nl>
Cc: Boot, Robert <R.Boot@amsterdam.nl>
Subject: Re: steunbrief - verzoek om e-mail ter bevestiging

Beste Annemarie,
Bij deze bevestig ik onderstaande.
Met vriendelijke groet,

Patrick van Beveren
Teammanager

Verstuurd vanaf mijn iPhone

> Op 3 sep. 2020 om 16:55 heeft Annemarie van Wezel <a.p.vanwezel@uva.nl> het volgende geschreven:
>
> Hoi Robert en Patrick,
> Zoals afgesproken even teruggegaan naar de penvoerder WUR; We kunnen jullie als partner meenemen als jullie spoedig via een email kunnen bevestigen dat er 15/9, bij goedkeuring van het MT, er een steunbrief conform format ligt om partner te zijn in AQUACONNECT. In de steunbrief dan ook omschrijving van inhoud inbreng zoals cash cofin van 50ke gedurende programma periode, en in-kind via datadeling en inbreng casuistiek.
> Vriendelijke groet, Annemarie

Letter of support

To: prof. dr. ir. H.H.M. Rijnaarts
Wageningen University & Research
Department Environmental Technology
Postbus 17
6700 AA Wageningen

Subject: Support letter for the research project ***Aquaconnect – P19-45***

Dear professor Rijnaarts,

Hereby I declare that we intend to support the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.htmI

Introduction of supporting Partner
As Oasen, we have been informed about your application in this call from NWO domain TTW. We are very interested in participating in the project.

oasen
drinkwater

2 september 2020

Ons kenmerk:
WMR/tm/2020-09-02

Oasen NV is one out of 10 drinking water utilities in the Netherlands. The core business is the production and distribution of drinking water (47 Mm^3/year) in the province of South-Holland, the Netherlands. Oasen NV produces drinking water for 780,000 people and 7,200 organisations. Water quality is the main priority, therefore Oasen NV invests continuously in the treatment plants, based on membrane filtration, the distribution network and its knowledge. The main drinking water source is (infiltrated) river Lek water (80%). Oasen NV is a public owned company. The company employs 250 staff and has a yearly turnover of €70 million.

We are interested in participation in the project because as a Water Supply Company we have a growing need for drinking water. Although we prefer sweet river bank filtrate water as our source, which is the best quality available, for the long term we see the necessity to investigate alternative sources like seepage water, brackish water or other sources.

These sources can be treated with membrane technologies that enable both strategic and operational management of water resources. Brackish water can be found all over our supply area, close to the customers. One particular interesting pilot project is the use of brackish ground water from beneath a deep polder and along the Old Rhine, which is investigated in the current Coastar project. The resulting theoretical hydrological, technical and cost evaluation of this project will end up in a decision about the continuation of this research with a Pilot-installation, aiming at a brackish groundwater extraction, R.O. filtration and re-injecting of the concentrate at large depths. Especially the re-injection of concentrate at large depths needs research on the scaling and crystallization of the supersaturated concentrate, the possibility of well clogging and the juridical and legal part of this solution with respect to the Water Frame Work Directive.

Oasen N.V.

Nieuwe Gouwe O.Z. 3
Postbus 122
2800 AC Gouda

T 0182 59 33 11
www.oasen.nl

KvK 290.10639
BTW 001998079 B01

Solutions provided will enable Oasen NV, responsible for drinking water quantity and quality in our region, to safeguard and control drinking water availability both on the long term. As such, the outcomes of the project are very relevant to us and will be taken into account for future investment
decisions.

Interest in AquaConnect research

Oasen NV has special interest in the work packages:

Workpackage 2 – Digital technologies to identify new groundwater resources and determine the impact of its extraction.
WP2.1. Regional high-resolution integrated groundwater-surface water modelling (PI: Prof. Dr. M. Bierkens, UU, 1 PhD & 1PD). Hyper-resolution and scalable coupled groundwater-surface water models will be developed that allow for calculation of current and future water supply, storage possibilities, the effects of human water use and the impact of local and regional application of chemical technologies to enhance water supply and water quality

Workpackage 3 – Risk assessment of cyclic water systems that include nature-based treatment and storage.
WP3.1. Risk assessment of reuse in cyclic water systems (PI: Prof. Dr. A. van Wezel, UvA, 1 PhD & 1 PD). A risk-assessment strategy to determine harmful chemicals in cyclic water systems will be developed by combining analytical chemical, molecular and biological tools, which provides quality targets for water treatment technologies.

Workpackage 4 – Chemical and physical technologies for fit-for-purpose water supply.
WP4.2. Managing and engineering quality effects of effluents, brines and sludges for application in soil and groundwater (PI: Prof. S. van der Zee, WUR, 1 PhD). A framework for integrated sustainability assessment of the effect of infiltrating treated effluents and sludges to soils to enhance crop production, **and brines to saline aquifers,** to minimize environmental impact will be developed by modelling and testing different environmental subsurface compartments.

2 september 2020

Ons kenmerk:
WMR/tm/2020-01-16

Workpackage 5 – Freshwater provision governance
5.1. Integrated assessment of financial, economic, legal and political conditions that allow regional key technology implementation (PI: Prof. D. Huitema, VU, 2 PhDs). A scientific assessment of socio-economic, political, legal and policy challenges that can either accelerate or impede the implementation of the key technologies developed within WPs 2 & 3 in a regional smart water-grid
5.2. Water system policy & design tool (PI: Prof. D. Huitema, VU, 1 PD in combination with Deltares, KWR, HZ & WEnR). Design of an integrated assessment tool for stakeholders that allows an institutional change in fresh water governance.

Workpackage 7 – Case-study demonstration. The applied knowledge institute researchers ensure inclusion of scientific findings of WP 2, 3 and 4 into demonstration and application in direct interaction with case-related stakeholders in Zeeuws-Vlaanderen, MRA, Zuid-Holland and the Higher Sandy Soils. AQUACONNECT PhDs will be linked to the (ongoing and planned) long-term field scale pilots and demonstrations, which are executed by the knowledge institutes within the framework of other research programs, such as COASTAR and Lumbricus (section 3.3), this way strengthening the scientific basis for the solutions applied. Each half year a one-day case specify R&D-to-design session will be conducted for each of the 4 cases with the end-users, stakeholders and scientists from WP1 and 2. These R&D-to-design workshops result in the logical and impact-driven implementation of research outcomes to the practical challenges of the authorities, governmental organizations and industries. Demonstration in the case-studies will lead to a toolbox of key technologies which can be implemented in a smart water-grid that can also be used in other regions in The Netherlands, and worldwide.

Description of support

Financial support

- The cash contribution will be a total of 50.000 Euro excl. VAT for the five year project;
- We estimate an in-kind contribution of 97 hours per year to support the PhD's and Post Docs by developing and realizing a pilot installation for research, delivering data, information, translation of the output from the research to the benefits of Oasen NV and active participation in the User Committee. This represents 486 hours with a rate 103 Euro/hour + 50.000 euro in-kind contribution for realizing a pilot equals 100.000 Euro.

In-kind Contribution				
Project	**Description of contribution**	**Quantity[1]**	**Unit cost/ Tariff[2]**	**Sub-total**
WP2.1 + WP3.1 + WP4.2 + WP7	Pilot RO installation including abstraction and (brine) infiltration well	1	€50.000	€50.000*
WP2.1 + WP3.1 + WP4.2 + WP7	Developing and realisation of a pilot RO installation including abstraction and (brine) infiltration well + assisting/supervising PhD/Post Docs	286 h	€103/h	*€29.400**
WP5	In-kind bijdrage	40 h/year	103 euro/h	*€20.600*
Total (in-kind contribution)				*€100.000*

[1] *man-hour/ quantity/ etc.*

[2] *Senior employee, everyone with an academic education = € 103/hour; junior employee, everyone with a college degree (Dutch HBO-opleiding) = € 71/hour.*

oasen
drinkwater

2 september 2020

Ons kenmerk:
WMR/tm/2020-01-16

**On the condition that Oasen will obtain a permit for the abstraction of water from the aquifer, for the re-infiltration of the brine into a saline aquifer and the disposal of RO permeate on surface water*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of the NWO Domain TTW Perspectief programme.

Yours sincerely,

prof. dr. ir. W.G.J. van der Meer
CEO
Oasen N.V.

Dow Benelux B.V.
P.O. Box 48
4530 AA Terneuzen
the Netherlands
Telephone: 0115 67 12 34

September 1st 2020

Dear professor Rijnaarts,

Dow Benelux is a subsidiary of The Dow Chemical Company. Dow was founded in 1893 in Midland, Michigan US and employs about 37,000 people globally today. Dow combines the power of science and technology to passionately innovate what is essential to human progress. The Company connects chemistry and innovation with the principles of sustainability to help address many of the world's most challenging problems such as the need for clean water, renewable energy generation and conservation, and increasing agricultural productivity.

The heart of Dow in the Benelux is in Terneuzen, Zeeuws Vlaanderen. With its 18 plants and approximately 1,700 employees Dow Terneuzen is the second largest production location of the Dow Chemical Company. As the largest employer of Zeeuws Vlaanderen, Dow has contributed to the economic and social success of the region for more than 50 years.

Dow has, in its location in Terneuzen, developed together with the regional partners Evides Industriewater and Water Board Scheldestromen expertise in the reuse of treated wastewater from both municipal and industrial sources, achieving a high level of process integration for Dow's facilities in Terneuzen.
Dow operates world scale chemical facilities around the globe and is increasingly facing fresh water availability issues. In these areas, where urban, industry and rural areas 'compete' for fresh water, cascading water applications based on a fit-for-use purification enable multiple cross-sectional reuse.

Dow Benelux BV has participated in the preceding project, the STW Perspectief program WATER NEXUS, and strives to be a partner in the proposed project AquaConnect.
The Water NEXUS project created the basis for an overarching vision on new concepts in water utilization and unit operations on a regional scale, allowing an optimum water distribution based on both availability, quality and demand.

Dow supports the long term reach in strategic fresh water sourcing as outlined by the AquaConnect project since even medium term future developments are hard to predict. Although Dow will make an effort to increase downstream water loop closure and water conservation (at the chemical site), Dow will remain dependent on external fresh water supply.

Registration no. Chamber of Commerce: 24104547

Several factors, of which its size and impact is yet uncertain, have to be managed on a broader and more comprehensive manner than they are today – among these are climate change consequences (salinization, weather extremes), infrastructure and economic development (Nieuwe Sluis, Westelijke Kanaaloever, Flanders), the raw material and energy transition towards a fossil free economy (changing water demand and usage patterns), increasing competition towards fresh water availability (Kanaalzone, Zeeuws-Vlaanderen, Flanders). Regional cross-border water basin modeling and scenario building will be crucial to identify the best approach, which may be anywhere between or a combination of combatting impact and adapting to change. As considerable investments and long term regional vitality are at stake, a science (and good practice) based program broadly supported by regional stakeholders is highly supported to make the necessary steps into the future.

In this project Dow will perform the following actions:

- Dow is an active member of the regional initiative Robust Water system Zeeuws-Vlaanderen, coordinated by the province of Zeeland – within this partnership partners from multiple sectors have committed themselves to actively support the development of a robust future-proof water system – Dow is supporting this initiative with a cash commitment of 15 K€/y and 10 K€/y as in-kind for the duration of the project.
- Dow will provide expertise in water reuse from multiple sources in various industrial applications, including the definition of process critical parameters for certain applications. Both personnel from Dow Benelux and those from the Environmental Technology Center will be participating in this project.
- Dow will facilitate the modelling of a regional implementation associated with the local infrastructure including green infrastructure and regional water streams. These activities will occur in close cooperation with AquaConnect project partners.

Category	Activity Description	Number (hours)	Cost price / tariff (€/h)	Total	Percentage attributed to the project
MSc/PhD employees	Attending project meetings	64	103	6592	100%
	Attending workshops	32	103	3296	100%
	Providing Expertise Input	192	103	19776	100%
BSc employees	Attending workshops	32	71	2272	100%
	Analytical work to support expertise input	144	71	8179	80%
	Grand Total			**40115**	

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NOW Domain TTW Perspectief programme.

Anton G. van Beek
President

Plein van de Verenigde Naties 11, Zoetermeer
t 088 347 50 00 | www.dunea.nl

dunea
DUIN & WATER

Return address: P.O. Box 756, 2700 AT Zoetermeer, NL

Wageningen University Research Sub-dept of Environ
Mental Technology
Mr. Prof.dr.ir. H.H.M. Rijnaart
P.O. Box 17
6700 AA WAGENINGEN

Date 3 September 2020
Subject Support letter for the research project Aquaconnect P19-45
Our reference B125220
Handled by Silvia van der Voort, s.voort@dunea.nl

Dear Mr. Rijnaart,

Hereby I declare that we intend to support the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html

Introduction of supporting Partner
Dunea is a public water company which supplies drinking water to the cities of The Hague, Leiden, Zoetermeer and surrounding municipalities. We expect to grow from 1.3 million customers to date to 1,5 million customers in the year 2040. As our water resources (the rivers Meuse and Rhine) are under increasing stress due to chemical spills and climate change (e.g. low river flows, salinization), Dunea aims to expand its resources portfolio in order to ensure future water supply. For that reason, we are currently exploring new water resources, including unconventional water resources such as brackish groundwater. Climate change will lead to increasing competition for fresh water sources in the Rhine-Meuse delta. Dunea is interested to cooperate with other water users in order to reduce the pressure on the water system, especially during prolonged periods of drought. Potential measures which need to be investigated in AQUACONNECT include subsoil water storage, use of unconventional water sources and cascading use of fresh water between different economic sectors (e.g. power generation, agriculture, industry). In addition, new water purification technologies need to be developed or optimized, especially with regard to the use of unconventional water resources. This fits well within the multi-sources portfolio which Dunea is currently developing.

Description of support
Financial support

- The cash contribution will be a total of 100.000 Euro incl. VAT for the five year project;
- We estimate an in-kind contribution of 1170 hours in total for the research period to support and cooperate with the PhD's and Post Docs. These 1170 hours with a rate of 103 Euro/hour represent 120.510 Euro as in-kind contribution.

dunea
DUIN & WATER

In-Kind Contribution

Project	Description of contribution	Quantity[1]	Unit cost/ Tariff[2]	Sub-total (euro)
WP2.1 Regional high-resolution integrated groundwater-surface water modelling	Pieter Dammers, senior geohydrologist, will support the research.	180 (1 hour/week)	103	18.540
WP2.2 Management of fresh groundwater resources using data-model assimilation and model predictive control	Melchior Polwijk, geohydrologist and modeller, will cooperate with the researchers.	360 (2 hours/week)	103	37.080
WP3 Risk assessment of cyclic water systems that include nature-based treatment and storage	Ton Knol and Karin Lekkerkerker share their wide expertise on the behavior of organic micropollutants during soil passage	270 (1,5 hours /week)	103	27.810
WP4 Chemical and physical technologies for fit-for-purpose water supply	Franca Kramer holds a PhD in membrane technology and is working on purification technology of a potential new source for drinking water, the Valkenburgse Meer. Franca will support the researchers.	180 (1 hours/week)	103	18.540
User Committee, workshops, evaluation sessions on research topics, conference	Karin Lekkerkerker will coordinate the contribution of Dunea.	180 (1 hour/week)	103	18.540
Total (in-kind contribution)				120.510

[1] *man-hour/ quantity/ etc.*
[2] *Senior employee, everyone with an academic education = € 103/hour; junior employee, everyone with a college degree (Dutch HBO-opleiding) = € 71/hour.*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of the NWO Domain TTW Perspectief programme.

Yours Sincerely,

Drs. W.M.E. Drossaert
CEO

Evides
industriewater

PO Box 4472
3006 AL Rotterdam

1-9-2020

Dear professor Rijnaarts,

Evides Industriewater is serving the industry with water services, like demiwater, industry water, wastewater treatment and water reuse. The annual amount of water delivered is around 100 mln m^3, for example in the Rotterdam harbor area and in the region Zeeuws Vlaanderen. For Evides Industriewater and for its clients it is essential to have access to robust and reliable water sources. To ensure availability of water in the future Evides is developing water reuse applications among other things.

Evides Industriewater wishes to participate in the Aquaconnect proposal because it fits in the strategy for water availability. The annual contribution will be €15k cash and €10k in kind for the assumed period of 4 years. The in kind contribution will be executed by process engineers of our R&D department as follows.

Description	Number	Cost price/tariff	Total
Junior process engineer	*250 h*	*71*	*17.750*
Senior process engineer	*215 h*	*103*	*22.145*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NOW Domain TTW Perspectief programme.

Your sincerely

Jan Robert Huisman Director Evides Industriewater

Glastuinbouw Nederland
morgen groeit vandaag

Louis Pasteurlaan 6, 2719 EE Zoetermeer
Postbus 447, 2700 AK Zoetermeer

+ 31 85 003 6400

info@glastuinbouwnederland.nl
glastuinbouwnederland.nl

Kvk 27294015
BTW 8172.64.437.B.01

Wageningen University & Research
Department of Environmental Technology
Prof. dr. ir. H.H.M. Rijnaarts
P.O. Box 17
6700 AA Wageningen

Dear professor Rijnaarts,

Glastuinbouw Nederland unites and supports greenhouse horticulture entrepreneurs, with as its main activities lobbying at national, provincial, and regional governments and creating innovative programmes for Labour, Energy, Planet Health and Water & Environment for the benefit of the entrepreneurial network. We represent 70% of the total greenhouse horticulture acreage in The Netherlands andencourage knowledge development and knowledge exchange between inspiring entrepreneurs Working on a responsible greenhouse horticulture industry with optimal entrepreneurs' conditions for our members is our challenge. We ensure collective solutions for a responsible, financially healthy, and future-proof sector. One of the future challenges for the Dutch horticulture is the year-round provision of high-quality water for use in the greenhouses in times of prolonged drought.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. Glastuinbouw Nederland acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 24.750,- (during 4 years). Within the Dutch horticulture-sector, there have already been many initiatives to develop water-grids for circular water systems. The in-kind contribution of Glastuinbouw Nederland is dedicated to connect AquaConnect to these initiatives and consists of:

- Providing information about ongoing circular water initiatives including state-of-the-art of currently used water-treatment technologies within the horticulture sector.
- Providing information about the required water quality for use in the Dutch horticulture, as context for the newly developed water treatment technologies
- Providing information about the water quality after use in the Dutch horticulture, as context for the newly developed water treatment technologies
- Identify the possibilities for demonstration of future smart water-grids including key water treatment technologies developed within AquaConnect in the Dutch horticulture.

Glastuinbouw Nederland
morgen groeit vandaag

- Communicating the progress and results of the project to the Dutch horticulture growers, as well as involving growers in the project where necessary.

Description	*Number*	*Cost price/tariff*	*Total*
Themespecialist Water	*60 hour/ year*	*103 euro*	*6.180 /year*

Due to time-constraints, it was not possible for Glastuinbouw Nederland to support Aqua-Connect with an in-cash contribution. However, Glastuinbouw Nederland acknowledges the value of AquaConnect for the Dutch horticulture and intends to provide an in-cash contribution (via Stichting Kennis in je Kas), which will be decided upon in September/October.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,

Ing. R.M. Paauwe Msc.
Director

hoogheemraadschap
Hollands
Noorderkwartier

Wageningen University & Research
Prof. dr. ir. H. Rijnaarts
Bornse Weilanden 9
6708 WG WAGENINGEN

Date	Your referrence	Contactperson
August 31, 2020		R.N. Koolen
Case nummer	**Registration number**	**Telephone number**
HHNK/16003613	20.0842692	+31725827310

Subject
Aquaconnect, Final support letter

Dear professor Rijnaarts,

Hereby I declare that we intend to support the MRA Demo Fresh Water Challenges Amsterdam Metropolitan Area and North-Holland within the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html and the draft proposal as prepared by July 9, 2020.

Introduction of supporting Partner
As a regional water authority, Hoogheemraadschap Hollands Noorderkwartier is a government organisation. As the regional water authority we ensure that:

- Inhabitants have dry feet;
- There is sufficient fresh water;
- There is sufficient clean water;
- Roads are safe.

Maintenance of the road system is an additional task of
Hoogheemraadschap Hollands Noorderkwartier.
Our board is democratically chosen and we have our own tax system. Our administrative organization is comparable to a city council. The general management can be likened to the council, the daily management to the aldermen, and the dyke warden to the mayor. Every four years, voters elect a new managing board.
Hoogheemraadschap Hollands Noorderkwartier plays a central role in everything to do with water in the region of North Holland above the North Sea Canal. In these efforts, we work closely with the Directorate-General for Public Works and Water Management (Rijkswaterstaat), the local county and council, stakeholder organizations, entrepreneurs, citizens, engineers and other specialists.

Hoogheemraadschap
Hollands Noorderkwartier
Postbus 250, 1700 AG Heerhugowaard
Stationsplein 136, 1703 WC Heerhugowaard

T 072-5828282
post@hhnk.nl
www.hhnk.nl

NL66 NWAB 0636 7537 78
KvK 37161516

The water authority organizes consultation groups and information meetings to share and discuss needs, wishes and possibilities.

Description of support
We are interested in participation in the project - especially the Demo Fresh Water Challenges Amsterdam Metropolitan Area and North-Holland - because the integrated approach and focus of the project - the development of innovative integrated solutions based on new physical and societal connections enabling innovative circular approaches, in line with our strategy to provide clean water services, human and environmental health and ecological save water bodies, especially regarding micropollutants and nutrients and our ambitions to create circular water solutions.
We support the Demo Case Integrated Smart Freshwater on Demand Amsterdam Metropolitan Area and North-Holland with in-kind activity and in a cash contribution of a total of € 40,000.

Our specification of the in-kind support of about € 20,000 both hours (number and/or tariff applied) and materials, are summarized in table format below:

Description	Number	Cost price/tariff	Total
Providing Knowledge of HHNK activities Demo's Wervershoof and supply to water cycle systems Noord Holland	40	€ 103	€ 4,120
Meetings and workshops	4*3*8	€ 103	€ 9,888
Report on Demo Circular Water	20	€ 103	€ 2,060
Other meetings and work sessions	40	€ 103	€ 4,120
Total			€ 20,000

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Signed by an authorized signatory

On behalf of the college of dijkgraaf en hoogheemraden (compare with major and alderman),

Signature: ----------

Name: E.L. Martha
Function: Head Division knowledge and development
Department Sanitation of the water authority Hoogheemraadschap Hollands Noorderkwartier

ICT Netherlands B.V.

Kopenhagen 9
2993 LL Barendrecht

13 juli 2020

Dear professor Rijnaarts,

ICT Netherlands B.V. (ICT), a part of the ICT Group, is a system builder for industry-specific and cross-industry solutions. With a track record spanning more than 40 years, ICT has both extensive multi-domain expertise and in-depth industry knowledge. In this way we contribute to a smarter world, in particular in the domains Cities, Industries and Healthcare. With more than 1400 professionals we help companies to develop further with smart, innovative, integrated and most of all challenging ICT solutions. Integrating these strengths into compelling technological solutions puts ICT in a unique position to help its customers make their business processes more efficient, flexible, simple, safe and – as a result – more sustainable.
ICT is an important contributor to the development of smarter cities. Improving the quality and performance of urban services is a necessity because of ongoing urbanisation and goes hand in hand with reducing resources and costs. ICT's solutions enable cities to deal with the complexity of population growth. Cities face increasing challenges in the field of water, energy, mobility, waste and the environment. These challenges call for smarter cities in which people, authorities, companies, machines and even products are connected to one another, exchanging information and inter- acting in real time. The Aquaconnect solution and the role of ICT in the project is an example of the ICT strategy in smarter cities.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of the Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. ICT acknowledges the importance of this program and commits itself to the research with an in-kind contribution of € 20.000,- and an in-cash contribution of € 20.000,-.

ICT has extensive experience in digital data and software systems for the water industry and is willing to share this expertise and support the development of the operational control solutions to optimally match demand and supply in smart digital grids. The in-kind contribution is dedicated to improving the connection between the scientific research in the

field of digital technologies, focusing on the work package "Real-time monitoring and model predictive control of smart water grids". The in-kind contribution consists of:

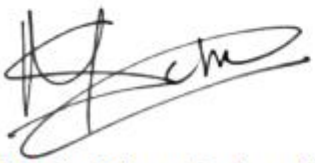
- (co)design of the system control architecture, focused on large-scale data connections and data integration, including optimal performance of the monitoring system to large scale users;
- (co)design of the monitoring app and required system architecture;
- (co)integration of the external water systems to prove actual usability of the system.

See the table below for a specification of the in-kind support:

Description	Number	Cost price/tariff	Total
Senior engineer architecture	*1*	*103*	*50*
Senior engineer design	*1*	*103*	*80*
Senior engineer integration	*1*	*103*	*65*

Obligatory paragraph by NWO:
We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.



Martijn Schram, Business Unit Manager Water & Infra

Wageningen UR
Prof.dr.ir. Huub H.M. Rijnaarts
Bornse Weilanden 9
6708 WG WAGENINGEN

August 7, 2020

Dear Professor Rijnaarts,

Hereby we declare that we intend to support the NWO-TTW Perspective Project 'P19-45 AQUACONNECT Climate robust water provision and management for delta regions', as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html and by the proposal as submitted.

Introduction of Supporting Partner
KnowH2O (SME) is an applied research and consultancy company on hydrology, water management, and water quality. We also provide project management services. Our customers are often water authorities, provinces and public service bodies in The Netherlands and abroad. Our main projects use desk studies, field trails, computer simulations, remote sensing, and GIS activities. Themes are usually related to agriculture and nature areas, hydrology of the vadose zone, drought and its effects, and to interaction between soil, groundwater, and surface waters. Because of these activities and related projects, the aim of this NWO-TTW project is highly relevant to us.

We have been working on freshwater supply issues, controlled drainage, sub-irrigation, and water-reuse for more than eight years, both experimentally and by computer modelling. We have been using surface water, groundwater, and treated wastewater from WWTP for agriculture. A complex process, as we seem to run into different kinds of obstacles like water quality, crop safety, and governance issues. We expect that AQUACONNECT will help us move forward on these issues, or at least provide us with more insights on these topics.

Description of Support
AQUACONNECT provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid.

KnowH2O
Watertorenweg 12
6571 CB BERG EN DAL
NL 83 INGB 0006 2713 22
KvK 59020229
BTW NL160164321B01
t +31 (0)6 23 22 49 68

info@knowh2o.nl
www.knowh2o.nl

KnowH2O is interested in and prepared to commit ourselves to the AQUACONNECT proposal. KnowH2O will contribute in-kind. We want to contribute to the integration of project results and to the translation of results to practical and integrated water management practices, useful in our consultancy activities. Our in-kind contribution is consists of:

- Provide information for study areas.
- Contribute to stakeholder redesign landscape workshops.
- Contribute to AQUACONNECT symposia or workshops.
- Link AQUACONNECT to the TKI KLIMAP project.
- Internal and external dissemination of the results.

Specification of annual in-kind support by KnowH2O in hours and cost (€).

Description	# Hours	Cost/hour in €	Total cost in € (excl. 21% VAT)
GIS-expert	16	95,=	1.520,=
Modelling expert	16	95,=	1.520,=
Senior Water Management Expert	16	130,=	2.080,=

The project duration is four years. Our total in-kind contribution is therefore € 20.480,= excl. 21% VAT.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation. Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief Programma.

Best regards,

G.A.P.H. van den Eertwegh, PhD
Owner/director

KnowH2O
Watertorenweg 12
6571 CB BERG EN DAL
NL 83 INGB 0006 2713 22
KvK 59020229
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KWR

Groningenhaven 7
Postbus 1072
3430 BB Nieuwegein
The Netherlands

P +31 30 606 95 11
I www.kwrwater.nl

Universiteit Wageningen (sub dept. ETE)
Attn. prof. dr. ir. H.H.M. Rijnaarts
Postbus 8129
6700 EV WAGENINGEN
The Netherlands

Subject	Support AquaConnect initiative
Date	27 July 2020
Our reference	20070067BS

Information
Ruud Bartholomeus
ruud.bartholomeus@kwrwater.nl

Dear professor Rijnaarts,

Hereby I declare that we intend to support the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html and the proposal as that will be submitted by September 2020.

Introduction of KWR

KWR Water Research Institute (www.kwrwater.nl) generates knowledge to enable the water sector to operate water-wisely in our urbanised society. At KWR, we have a sense of professional and social responsibility for the quality of water. Our scientific findings and the resulting practical innovations contribute, worldwide, to a sustainable water provision in the urban water cycle.

'Bridging Science to Practice' is KWR's motto. Our researchers work at the interface of science, business and society. Their strength lies in their translation of scientific knowledge into applicable, practical solutions for end-users in the Dutch and international water sector. We have built a solid reputation as top-level innovation accelerators and international network builders, and increasingly play a coordinating role in national and international collaborations. KWR is an independent entity, with the Dutch and one Flemish water company as its shareholders.

Description of support

In the past decades, KWR has built a solid reputation in developing and implementing integrated water resources management and water reuse concepts for drinking water, agriculture and industry, in the Netherlands and abroad. We have developed these solutions in close cooperation with end-users, in research projects and field pilots, and in knowledge programs such as COASTAR (www.coastar.nl) and WiCE (Water in the Circular Economy, https://www.kwrwater.nl/en/samenwerkingen/collectief-onderzoek-water-circulaire-economie/). Circular thinking and integrated solutions form the basis of these programs, similar to the AQUACONNECT initiative.

The research done within AQUACONNECT will help us to build a sound scientific basis for technological and nature based solutions for integrated water resources management. We are therefore interested in and will commit ourselves to the AQUACONNECT project. We intend to contribute €25,000 cash and €75,000 in-kind in men hours, contributing to case studies, integration of the results, and translating results to our wide network in the water sector. In particular, we intend to:

- link the AQUACONNECT project and its researchers to ongoing and foreseen field pilots on alternative water resources, water storage and water reuse, within the framework of the COASTAR and WiCE knowledge programs;

KWR

- communicate the scientific output of AquaConnect with regional stakeholders in the case-study regions that are described in the AquaConnect proposal;
- guide stakeholders in the case-study regions with demonstration and implementation of the in AquaConnect developed technological solutions and decision support tools for operational water management.

Description	Number	Cost price/tariff	Total
Principal scientist	*416*	*103*	*43k€*
Scientific researcher (senior)	*312*	*103*	*32k€*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,
KWR Water Research Institute

Prof. Dragan Savic FREng
Chief Executive Officer

Idsart Dijkstra MSc MBA
Manager Water Systems and Technology

Wageningen UR

att: prof.dr.ir. H. Rijnaarts

Bornse Weilanden 9

6708 WG Wageningen

Doetinchem, September 2, 2020

Dear professor Rijnaarts,

Nijhuis Industries delivers 'solid solutions in a fluid world' as a response towards a greener economy. Nijhuis is aiming to turn cost centers into profit centers with solutions for sustainable water use and resource recovery. To accommodate the customer requirements, Nijhuis offers water and resource recovery technology to meet today's challenges, as well those of the future, across a wide range of industries and municipalities in today's 'fluid' world. With more than 2600 references sites and activities in over 130 countries around the globe, it is our ambition to help customers and deliver solutions to:

- Reduce the amount of (waste)water and effluent charges;
- Reuse treated effluent or process water;
- Recover water and resources from your waste and (waste)water.

For Nijhuis, an important innovation in the field of water technology is the development of advanced physical-chemical (including electrochemical) methods for water purification. These technologies allow a significant reduction of the amount of chemicals used for water treatment. Furthermore, combinations of these technologies (for example nanofiltration and electrodialysis) can be employed to produce water fit for purpose. The demand for these technologies for (partial) desalination, micropollutant removal and discoloration is high, not only in The Netherlands, but also abroad.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid.

Nijhuis Industries acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-cash contribution of € 40.000,- and an in-kind contribution of € 9.940,-.

Nijhuis Industries is particularly interested in the water treatment pilot that is part of work package 4. This pilot includes a nanofiltration (NF) and electrodialysis (ED) treatment step, and Nijhuis acknowledges the importance to develop innovative technological solutions to cost-effectively treat water streams with low salt concentrations and low concentrations of organic pollutants. Nijhuis will contribute to this pilot.

Furthermore, Nijhuis is interested in a technological and market analysis to compare various treatment systems (treatment trains), including NF, RO and ED, for (partial) desalination, discoloration and micropollutant removal. Wageningen University & Research (Environmental Technology group) will supervise, in collaboration with Nijhuis, MSc student(s) to conduct this analysis.

The in-kind contribution is dedicated to the demonstration of the within AquaConnect developed innovative nanofiltration / electrodialysis combination to treat water fit-for-purpose in one of the AquaConnect case-study regions. The in-kind contribution is specified below.

Description	Number	Cost price/tariff	Total
Technical Support in development pilot	140	71	9940

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,

Menno Holterman

CEO

Letter of Support

North Sea Port Netherlands N.V.
Schelpenpad 2
4531 PD TERNEUZEN

Uw referentie: -
Onze referentie: 0017-2069358260-10581
Contactpersoon: Gerjo Bommeljé
E-mail: gerjo.bommelje@northseaport.com
Onderwerp: Letter of Support NWO Perspectief AquaConnect
Datum: 24 augustus 2020

Dear Professor Rijnaarts,

North Sea Port, as a port authority, is responsible for the handling of the shipping traffic, construction and maintenance of port infrastructure and the sustainable development of the port area towards the future. A port ecosystem is undeniably intertwined with the watersystem. Therefore North Sea Port is heavily depending on the services being provided by the watersystem in order to execute our core tasks.
For example the waterlevels needed to ensure the accesiblity of the port and (fresh) water as a raw material for the port's businesses and industries are some of our main priorities.

AquaConnect aims for developing new scientific concepts for solutions that can ensure future fresh water provision. New key digital and chemical technologies, and innovative water governance approaches are developed that together form the base to design alternative fresh water provision grids.
North Sea Port acknowledges that these innovative water management solutions can make a positive contribution to the future development of the port while ensuring the current servicelevels of the port. Besides that, AquaConnect is a perfect example of how to strive for industrial symbiosis, one of the key points of attention of North Sea Port.

We recognize the value and importance of the NWO Perpectief AquaConnect and will endeavour to provide support and input in relation to our competences, capabilities and availability. Therefore we will provide in both an in-kind of €2.500/y (35h/y, HBO-educated) as well as a cash contribution of €2.500/y to the NWO Perspectief AquaConnect.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation. Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

The undersigned, Daan Schalck, in the capacity of CEO of North Sea Port hereby confirms its support to AquaConnect.

Daan Schalck
CEO

nx filtration

Institutenweg 35
7521 PH Enschede
The Netherlands

+31 (0)850 479 900
info@nxfiltration.com
www.nxfiltration.com

Wageningen UR
Att: prof.dr.ir. H. Rijnaarts
Bornse Weilanden 9
6708 WG Wageningen

Concerns: support letter AquaConnect

Date: Enschede, 3 spetember 2020

Dear professor Rijnaarts,

NX Filtration (NX) develops and produces membranes for treating water and filtering beverages. NX specializes in advanced hollow fiber membrane modules for nanofiltration, ultrafiltration, and microfiltration applications.

NX's nanofiltration membrane technology is capable of selectively removing organics from polluted water, including micropollutants, color, antibiotics, PFAS, bacteria and viruses. This has resulted in new and simple processes for the treatment of water, the reuse of wastewater and the production of potable water.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid.

For NX a very important research topic is to further improve the module design for hollow fiber nanofiltration to further optimize mass transfer with novel geometries and new membrane materials. This will enable NX to apply it's unique separation at the low cost and high efficiency required for the envisaged large scale applications.

NX acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-cash contribution of € 25.000,- and an in-kind contribution of € 90.950,-.

nx filtration

The in-kind contribution (specified below) is dedicated to:

- Development of a pilot-scale demonstration system with nanofiltration, based on the scientific findings of AquaConnect, to treat water fit-for-purpose.
- Co-development of specific out-to-in support membranes, and produce them on an industrial scale
- Development of an out-to-in test module

Description	Number	Cost price/tariff	Total
Materials		40.000	40.000
Technical support in:	500	71	35.500
	150	103	15.450
Development pilot			
Development support membranes			
Development out-to-in module			

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Your Sincerely,

M.A. Staatsen

Signature

Enschede, 4-9-2020

Place, date

D.W.F. Riefel

Signature

Enschede, 4/9/2020

Place, date

Port of Rotterdam

Wageningen University & Research
Sub-dept. of Environmental Technology
Prof. Dr. Ir. H.H.M. Rijnaarts
P.O. Box 17
6700 AA WAGENINGEN

17 JULI 2020

Date
Our reference HBR-1927800
Number of annexes None
Contact Marc Eisma
Telephone 06-5194 7358
Fax (010) 252 10 20
Email m.eisma@portofrotterdam.com

Subject Support letter for the research project AquaConnect - P19-45

Dear prof. Rijnaarts,

Our mission is to ensure that the port is a safe and healthy environment, to limit climate change and to create employment opportunities.
Availability of freshwater is one of the key assets for port industry. Due to climate change and sea level rise the port area will face an increased penetration of salt water from the sea. Together with the Water Boards we try to ensure a sufficient supply of freshwater to port industries from lake Brielse Meer. The drought of 2018 in addition is a threat from the rivers for our fresh water supply. We are currently in the process of optimizing the management by improving our monitoring system and building an additional water inlet. This will secure the fresh water supply until 2050. We will have to come up with additional measures to protect our fresh water lake for both sea level rise and low river water events in the future.
We will have to ensure our fresh water supply on the longer term. The case studies in AquaConnect can provide building stones for climate proof solutions to keep our water management sustainable and robust in future. An alternative sources of fresh water for the industry that is investigated is the reuse of effluents from wastewater treatment plants. But also possibly regenerating fresh water from brackish groundwater of surface water are looked into, by use of sustainable and energy economical desalination. The groundwater underneath the port could be an alternative source, also in combination with thermal purposes.
Within AquaConnect digital technologies are designed and developed to come up with the most optimal infrastructure to support water with different qualities and linking supply and demand. With the developed and proven knowledge from the case studies could provide elements for future solutions for the ports industry, for building a long term climate proof and sustainable fresh water supply.

Port of Rotterdam

17 JULI 2020

Date
Our reference HBR-1927800

The Port of Rotterdam Authority is therefore interested in the AquaConnect research proposal and specifically to come up with digital designs for added fresh water supplies in the future.
The Port of Rotterdam Authority could commit itself to the research in kind, by providing the necessary port information and help translate the output from the case studies to the Rotterdam port situation. Please contact Marc Eisma, advisor at my department, who coordinates this topic, for further information.

In-kind Contribution				
Project	**Description of contribution**	**Quantity[1]**	**Unit cost/ Tariff[2]**	**Sub-total**
Workpackage 2 and 5	Data preparation and translation of output from the case studies to the Rotterdam port situation	80	103	8.240
Total (in-kind contribution)				8.240

[1] *Man-hour/ quantity/ etc.*
[2] *Senior employee, everyone with an academic education = € 103/hour; junior employee, everyone with a college degree (Dutch HBO-education) = € 71/hour.*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation. Furthermore we are aware that the above mentioned project is part of a NWO Domain AES Perspectief programme.

Yours sincerely,
Port of Rotterdam Authority

Eric van der Schans
Director Environmental Management

Provincie Noord-Brabant

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www.brabant.nl/route

Universiteit Wageningen
Attn. Prof. Dr. Ir. H.H.M. Rijnaarts
Postbus 8129
6700 EV WAGENINGEN

Onderwerp
Steunbrief project Aquaconnect

Datum
28 juli 2020
Ons kenmerk
C2267396/4740017
Uw kenmerk
nvt
Contactpersoon
P.L.M. (Peter) Ramakers
Telefoon
(06) 18 30 33 82
Email
pramakers@brabant.nl
Bijlage(n)
-

Dear Prof. DR. Ir. Rijnaarts,

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources.

Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid.

The province of North Brabant acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 20.000,- and an in-cash contribution of € 20.000,-.
The in-kind contribution is dedicated to Deltares and her partners and consists of:

- Provide data, existing tools, and other information for study areas.
- Contribute to stakeholder redesign landscape workshops.
- Contribute to AQUACONNECT symposia or workshops.
- Link AQUACONNECT to other programs like Klimap.
- Internal and external dissemination of the results.

The province of Noord-Brabant is a governmental organisation with more than 1000 civil servants. The province is, among other things, responsible for nature,

Provincie Noord-Brabant

environmental and water management in the Southern Dutch province Noord-Brabant.

Datum
28 juli 2020
Ons kenmerk
C2267396/4740017

Brabant is an European top region regarding knowledge and innovation. The provincial government invests in Brabant to sustain this position in the future. Within this frame we will also invest in smart beehives as an innovative monitor of biodiversity.

You can formalize the contribution of the province of Noord-Brabant to the project through a budget subsidy

If you would like more information about this letter, please contact Mr. P. Ramakers

Gedeputeerde Staten van Noord-Brabant,
namens deze,

T. Renner,
programmamanager Water en Bodem

In verband met geautomatiseerd verwerken is dit document digitaal ondertekend.

Provincie Zeeland
Abdij 6 4331 BK Middelburg
Postbus 6001 4330 LA Middelburg
+31 118 631011
IBAN NL08 BNGH 0285010557

Gedeputeerde Staten

WUR Wageningen University
T.a.v. Prof. Dr. Ir. HHM (Huub) Rijnaarts

onderwerp	kenmerk	behandeld door	verzonden
Steunbrief Aqua connect	20025750	Drs. T.B.M. Westerhof +31 118 631928	

Middelburg, 1 september 2020

Geachte professor Rijnaarts,

Wij hebben uw verzoek ontvangen ten behoeve van het onderzoeksprogramma AquaConnect, welke deel uitmaakt van een NOW Domein TTW Perspectief programma. Zoals in de intentieverklaring d.d. 29 november 2019 van de provincie Zeeland al is aangegeven, zijn we geïnteresseerd in deelname aan uw onderzoeksprogramma AquaConnect.

De provincie Zeeland richt zich op milieuvraagstukken die te maken hebben met klimaatverandering (zoetwatervoorziening), circulaire economie, energietransitie, natuurontwikkeling en nieuwe manieren van samenwerking. Zo zijn we gestart met een programma genaamd Zeeuws Deltaplan Zoet Water. Het doel van dit programma is om ervoor te zorgen dat de provincie in 2050 veerkrachtig is op het gebied van zoet water. Er wordt gekeken naar de mogelijkheden om zoet water zo effectief mogelijk te gebruiken.

Middels deze brief delen wij mede dat wij de samenwerking graag aangaan en een bedrag reserveren van € 100.000,-- ten behoeve van de cofinanciering aan het 4 jaar durende onderzoeksprogramma AquaConnect voor het doen van onderzoek naar een Robuust Watersysteem in Zeeuws-Vlaanderen. Daarnaast zijn we bereid 30 - 35 uur te investeren, wat neerkomt op ongeveer € 4.000,-- in natura per jaar.

Aan deze toezegging verbinden wij de volgende voorwaarden:
- Een positieve beslissing op uw aanvraag in het NOW Domein TTW Perspectief programma.
- Cofinanciering door ander regionaal betrokken partijen zoals Dow Benelux, Evides Industriewater, Gemeente Terneuzen, North Sea Port,
- Deelname van HZ University of Applied Sciences in de uitvoering van het project.

Wanneer aan bovengenoemde voorwaarden kan worden voldaan, kunt u een definitieve subsidieaanvraag indienen, welke conform het Algemeen subsidiebesluit Zeeland 2013 zal worden getoetst.

Hopende u hiermee voldoende geïnformeerd te hebben.

Met vriendelijke groet,

gedeputeerde staten,

Drs. J.M.M. Polman, voorzitter

A.W. Smit, secretaris

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Date:	3 August 2020	Contact name:	Paul Roeleveld
Your reference:		Telephone:	+31 6 13 66 69 85
Our reference:	BZ1180WATCO2008031600	Email:	paul.roeleveld@rhdhv.com
Classification:	Confidential		

Support letter AquaConnect

Dear professor Rijnaarts,

Royal HaskoningDHV is an independent international engineering and project management consultant with over 130 years of experience. Royal HaskoningDHV can call upon a large expert base of over 6,000 employees, of which more than 1,200 are active in the water sector. Royal HaskoningDHV is, together with clients and partners, already for more than 50 years investing in the development of innovative technologies, from laboratory to pilot scale and towards the first full-scale implementation. This is nowadays mainly stimulated by the driver for resource recovery and water reuse from wastewater. Our services cover the whole spectrum: policy, master planning, consultancy, design, engineering, asset management, environmental and social impact assessments, financial engineering, modelling, data management, products realization and operation & maintenance.

Since the drought from 2018 we are aware that drought damage is also a serious risk for The Netherlands, especially in the sandy soil provinces and the provinces in the western part of The Netherlands. The years 2019 and 2020 are only convincing that situations of drought are becoming a stable trend and that this asks for multiple solutions on regional and local level. For that we strongly support all objectives of the scientific program AquaConnect.

Within our Innovation Program Water Technology, the transition of wastewater treatment plants to water factories is an important theme for our business development. We are developing several technological concepts for water reuse, like additional treatment of effluent from biological treatment systems and innovative physical-chemical treatment systems for municipal wastewater. However, the problem of drought damage can't only be solved by developing new technologies. It is also crucial to look for temporarily buffering of freshwater, sustainable recharge options and to induce a step change in the current paradigm in freshwater governance. All these themes will be covered in AquaConnect and more insight into these themes will support the implementation of our technologies and concepts in practice.

Royal HaskoningDHV

With regard to the different cases, the sandy soil provinces have our highest interest and priority. For the Amsterdam Metropolitan area we have a medium priority and for the provinces Zuid-Holland and Zeeland we have a low priority concerning our contribution to AquaConnect.

With this support letter we state that HaskoningDHV Nederland B.V. is interested and committed to the scientific program of AquaConnect. Based on that statement we offer an in-cash contribution of € 30.000,- (total in four years, € 7.500,- each year). As in-kind contribution we offer an input based on hours with a value of € 50.000,- (total in four years). For this budget in hours we propose the following activities:

- data gathering for research activities;
- organization of co-creation sessions with stakeholders;
- global design activities of concepts for water reuse;
- setting-up business cases;
- coordination of the case for the sandy soil provinces.

In discussion with the program director of AquaConnect we will determine the final list of activities.

In the table below a further specification is presented of our in-kind contribution. For this it is important to mention that we have an agreement with Rijksdienst voor Ondernemend Nederland (RVO) for the application of the integral cost systematics (IKS) for subsidized projects which are subject to the "Kaderbesluit Economische Zaken subsidies". The presented hour tariffs in the table are according to this agreement with RVO.

Description	Number	Hour tariff	Total
Paul Roeleveld Business developer water reuse	80	193,40	€ 15.472,-
Sigrid Scherrenberg Innovation manager water reuse	120	145,90	€ 17.508,-
Krisjan van Laarhoven Junior specialist water reuse	235	72,40	€ 17.020,-
Total			**€ 50.000,-**

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Sincerely yours,
HaskoningDHV Nederland B.V.

Franc van der Wielen
Director Advisory Group Waste Water

Shell Global Solutions International B.V.
Grasweg 31
1031 HW Amsterdam
Netherlands
Tel +31206303216
Mobile +31655123467
Email hp.calis@shell.com
Internet www.shell.com

Prof. H.M. Rijnaarts
Environmental Technology
Dep. of Agrotechnology & Food Sciences
Wageningen University Research Centre

Bornse Weilanden 9, 6708 WG Wageningen
P.O. Box 17, 6700 AA Wageningen

August 4th, 2020

Subject: AquaConnect

Dear Professor Rijnaarts,

On behalf of Shell, I'm happy to commit our contribution to the AquaConnect project. This letter provides some background and details on this commitment.

We believe that AquaConnect fits well with Shell's purpose: powering progress together by providing more and cleaner energy solutions. This purpose implies that we carefully consider the potential environmental impact of our activities and how local communities might be affected during the lifetime of a project. We aim to comply with all applicable environmental regulations, continually improve our performance and prepare for future challenges and opportunities. We carefully manage our waste production, water use and discharges. We design and operate our facilities to help reduce freshwater use, and we tailor our use of fresh water to local conditions because water constraints affect people at the local or regional level. We develop collaborative solutions to save, reuse and recycle water – often applying innovative technologies to do so. We champion open innovation and work closely with universities, non-governmental organisations and industry associations to share knowledge and ideas to improve the way we use water and prepare for the future.

Shell's interest in AquaConnect is to establish a firm deployment framework for the re-use of waste streams such as biosludge and effluent for agricultural purposes. Gaining a thorough understanding of the fate of substances contained in these streams in this application fits with the medium to long-term risk mitigation, allowing sustainable re-use of such waste streams.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources.

Demonstration of these smart water-grids will occur in different regions of The Netherlands and internationally, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. Shell acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-cash contribution of € 100,000 and an in-kind contribution of € 6,180. The in-kind contribution is dedicated to establishing a connection between AquaConnect and the Shell project 'Greening the Desert' in Qatar in the context of international outreach and consists of

- Including a case study in AquaConnect with extreme conditions (desert, brackish water) for the re-use of biosludge and effluent in agriculture.
- Information-exchange about Shell initiatives for circular water systems in the context of 'Greening the Desert' in Qatar.
- Identifying the possibilities for demonstration of the in AquaConnect developed smart water-grids in Qatar.
- Connecting AquaConnect with relevant regional stakeholders that are required for executing such a demonstration-project in Qatar.

Description	Number	Cost price/tariff	Total
Senior Water Treatment and Integration Technologist	*40*	*103*	*4120*
Environment Manager Water	*20*	*103*	*2060*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,
Shell Global Solutions International B.V.

HP Calis
General Manager

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Perry.deLouw@deltares.nl

contactpersoon
B. Worm

doorkiesnummer
06-21882531

uw kenmerk

ons kenmerk
Z-1712701/20088140

datum
24 augustus 2020

bijlage(n)

Onderwerp
Support letter Aqua-Connect

Dear professor Rijnaarts,

Waterboard Vechtstromen, in the eastern part of the Netherlands, is suffering now for years of severe drought issues. The working area is 220.000 ha large. In this area we have to provide for enough fresh water of an acceptable quality and prevent land from floodings. In summertime, only 40% of this area can be provided by additional water from the river Ijssel (i.c. Rhine). In 60% of our working area we have to deal with drought problems and try to solve them with new, more climate proof solutions. Those solutions can be technical and/or more natural (building with Nature). We are searching for answers how to deal in the best way with the effects of climate change. Which measurements are good, in which areas, how to combine them with other measures to make them more effective, what influence do they have on the other occasional problem of 'water too much' (floodings) etcetera. That's why we also funded the research program 'Lumbricus', which is now ending this year, but already has a successor in the program 'KLIMAP'. Hence we are searching for the best measures to become climate resilient, and the way to get there (what policy and strategy is needed?). Therefore we like to contribute to the AquaConnect proposal, thinking/hoping that it will help us in this search for the right and most effective way to become climate resilient.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the

allow full-scale implementation of the smart water-grid. Waterschap Vechtstromen acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 10,000,- and an in-cash contribution of € 20.000,-. (4 years; €5.000,- a year) The in-kind contribution consists of hours (cost-prize staff-member is around € 85 - €100 per hour; that depends on the function) made by our staff members to:

- Provide desired data, existing tools, and other information for study areas.
- Contribute to stakeholder redesign landscape workshops.
- Contribute to AQUACONNECT symposia or workshops.
- Active linking AQUACONNECT to other programs like KLIMAP.
- Internal and external dissemination of the results (if they are proven valuable).

The exact number of staff-member-hours is not to be estimated in a realistic way at this stage now. It is strongly related to the kind of questions/requests we will receive from the AquaConnect project once it has really started, but it will be in the range of total 100 – 120 hours during the course of this research project.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,

J.P. Wiegmans, teamleider Strategie & Omgeving

brabant Water

Dear professor Rijnaarts,

Hereby I declare that we intend to support the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html and the proposal as that will be submitted by September 2020.

Brabant Water is the drinking water company of the Province of Brabant and supplies drinking water to approximately 2.5 million customers. Brabant Water is responsible for the abstraction of groundwater, the treatment of groundwater to drinking water and the distribution to its customers. Brabant Water operates on the sandy uplands in the south of the Netherlands, a region under increasing climate stress, including prolonged droughts as experienced in 2018, 2019 and 2020.

To safeguard future water supply and guarantee sufficient drinking water of excellent quality at all times, it is crucial to increase the resilience of the whole water system of the sandy uplands. This may include new strategies for the management of the natural water system, for example by promoting groundwater recharge, and the use of alternative water resources by industries and agriculture, as an alternative to using sparse groundwater. The research done within AQUACONNECT will help to build a sound scientific basis and initiate the technological and societal innovations that are needed to make the transitional change towards a climate-robust water provision and management.

Brabant Water intends to contribute to AQUACONNECT with €25,000 cash and €6,592 in-kind in men hours (64 hours, senior employee, hourly tariff €103). In particular, we intend to:

- Support the AQUACONNECT project and researchers, by sharing our experiences and practical knowhow of governance issues, water system functioning, and water treatment, and by reflecting on AQUACONNECT project results;
- Communicate the scientific output of AquaConnect within our company and with our regional stakeholders;
- Translate the project outcomes to our own company and our technological and corporate processes.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,

2/9/2020

Dr.ir. J.O.J.C. Verberk
Sectormanager Production

STICHTING
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Wageningen Universiteit
T.a.v. de heer prof. dr. ir. H.H.M. Rijnaarts
Postbus 17
6700 AA WAGENINGEN

Mailen naar: huub.rijnaarts@wur.nl
CC naar thomas.wagner@wur.nl

ONDERWERP Letter of support Aquaconnect
DATUM Amersfoort, 1 september 2020
ONS KENMERK JG200901002/424200/CU
UW KENMERK

Dear professor Rijnaarts

I am writing this letter to express our intention to support the project proposal entitled "AquaConnect". Our contribution is subject to a positive recommendation from the STOWA Program Committee on Waste Water Systems at September 17. As soon as possible, but no later than September 22, STOWA will inform you about the recommendation of the Program Committee.

STOWA (Acronym for Foundation for Applied Water Research) is the knowledge centre of the regional water managers (mostly the Dutch Water Authorities) in the Netherlands. Its mission is to develop, collect, distribute and implement applied knowledge, which the water managers need in order to adequately carry out the tasks that their work supports. To this end STOWA initiates and funds projects that are relevant for the knowledge base of the Dutch Water Authorities.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. STOWA acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 9.600,= and an in-cash contribution of € 100.000,= (VAT and other taxes are included). The in-kind contribution consists of organising a workshop to consult stakeholders, involved water authorities and involved participants of other related projects like "Zicht op elke druppel", "Waterfabriek Wilp", etc. From our point of view a good coordination with other projects is a key parameter for success.

Our specification of the in-kind support of about EUR 9.600--, is summarized in table format below:

Description	*Number*	*Cost price/tariff*	*Total*
Meetings and workshops	4*3*8	EUR 100	EUR 9,600
total			EUR 9.600

stowa

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Sincerely,

Managing director STOWA
ir. J.J. (Joost) Buntsma

Kingdom of the Netherlands

Wageningen University & Research
Sub-dept. of Environmental Technology
Attn. Prof. dr. ir. H.H.M. Rijnaarts
P.O. Box 17
6700 AA Wageningen

Economic Affairs Santiago

Royal Netherlands Embassy
Santiago de Chile
Location code 503
P.O. Box 12200
2500 DD The Hague
The Netherlands
www.minbuza.nl/en

Contact
Frans E. Janssen
T +56 2 2756 9227
F
frans.janssen@minbuza.nl

Cc
H. van Duijne, Deltares

Date 03 September 2020
Re Support letter for the research project AquaConnect - P19-45

Dear prof. Rijnaarts,

The embassy of the Kingdom of the Netherlands in Chile, through this letter, confirms its interest and commitment to the AquaConnect project as it is being set up and then specifically with regards to a mirror project in Chile. This project supports our G2G and K2K objectives for our water cooperation with Chile and also can lead to concrete business opportunities.

The support will consist of local coordination of the project, act as an intermediary between the two countries and its respective consortiums working on the scientific and applied science and technology parts and support raising awareness in public, knowledge and private sectors in Chile, not in the least by linking our name to it.

We will contribute with an initial EUR 8750 in the year 2020 in cash to support the start-up of the mirror project AquaConnect project in Chile. Next to that we will ensure support as need be by our trade advisor water during the period of the start-up. Once the project is formalized and will be executed, we will study with our water partners in the Netherlands (RVO, NWP, ministry of IenW) how we further support with cash and/or in-kind.

We have read and have been fully informed about the application. We state that we will actively participate in the End User Committee (EUC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain "TTW Perspectief" program.

Yours sincerely,

Mw. drs. L.C. den Breems,
Counselor

Stibbe

Amsterdam Brussels Dubai London Luxembourg New York

mr. A. Collignon
Advocaat

Advocaten en notarissen
Beethovenplein 10
Postbus 75640
1070 AP Amsterdam
Netherlands
T +31 20 546 01 39
F +31 20 546 07 10
anna.collignon@stibbe.com
www.stibbe.com

Date
3 September 2020

Per email: huub.rijnaarts@wur.nl

Dear Professor Rijnaarts,

Stibbe is one of the leading law firms in the Netherlands in the area of Administrative law. Our Environment & Planning team is the largest team of its kind in the Netherlands. Our experts have in-depth knowledge of all aspects of environmental and planning law. We not only advise and litigate cases, but also maintain close contact with universities, the Dutch Parliament and Ministries. We are involved in cases that create relevant new case law, contribute to academic articles, and play a role in drafting and commenting on new legislation.

Stibbe is known for its focus on high-profile and complex cases. The issues raised by periods of drought, a problem facing the Netherlands now and in the future, definitely fits this category. Alleviating water scarcity is a complex problem involving many stakeholders, with significant consequences for individuals, nature areas and industry. Our Environment & Planning practice focuses on the two latter sectors, and foresees that both could be highly affected by future water scarcity and by measures taken by governmental and private actors to alleviate this problem. Therefore, Stibbe is active on this topic, including providing legal advice in this area to several stakeholders (industrial and governmental actors) as well as contributing to the scientific knowledge on this topic. Stibbe values its long-standing and close connection with academia and universities, which is reflected by the fact that several employees regularly publish articles in professional journals, hold PhD degrees or even have professor positions at several universities in the Netherlands.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water grids, based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand

Stibbe

fresh water supply based on currently unexploited water resources. Demonstrations of these smart water grids will take place across various regions of the Netherlands, accompanied by a scientific assessment of the financial, economic, legal and political conditions required for full-scale implementation of the smart water grid.

Stibbe acknowledges the importance of finding solutions for regional water provision problems, and commits itself to the research performed by AquaConnect with an in-kind contribution of EUR 6,000 to facilitate a workshop at Stibbe, and an in-kind research contribution of EUR 10,300 carried out by Annalies Outhuijse, LLM PhD. Stibbe's in-kind research contribution will consist of:

- Exchanging knowledge on legal and administrative aspects of fresh water governance related to the AquaConnect case studies with the researchers in WP5;
- Supervising the PhD in WP5, amongst others during a short internship at Stibbe.
- Organising a workshop dedicated to exchanging knowledge about legal and administrative aspects of fresh water governance with AquaConnect stakeholders;

Description	Number	Cost price/tariff	Total
Specialist legal and administrative aspects – Annalies Outhuijse, PhD LLM, associate at Stibbe.	*100*	*103*	*10,300*
Facilitating a workshop at Stibbe			*6,000*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Kind regards,

Anna Collignon
Partner Administrative law, team Environment & Planning

Royal Swinkels
family brewers

Swinkels Family Brewers N.V.
De Stoter 1
Postbus 1
5737 ZG Lieshout
Nederland

T +31 499 428 111
F +31 499 428 269
info.nl@swinkelsfamilybrewers.com
swinkelsfamilybrewers.com

Rabobank
BIC RABONL2U
IBAN NL82 RABO 0101 0543 43
BTW NL001358.455.B01
K.v.K.-nummer 17007387

July 28, 2020

Dear professor Rijnaarts,

Swinkels Family Brewers (SFB) is a family owned company with three breweries in the Netherlands. SFB is caring for its environment with a focus on circularity. In Lieshout, the south of the Netherlands, the Bavaria Beer Brewery extracts a large amount of groundwater and discharges treated waste water to the surface water. At the same time, neighboring farmers invest in sprinkler irrigation using groundwater to maintain their crop production during drought periods. This leads to increasing pressure on the regional groundwater availability. To reduce the water footprint of the brewery and the abstractions of farmers, we intend to deliver treated wastewater to nearby agricultural fields by sub irrigation. However, water quality and infiltration capacity of systems are important issues which currently hamper large scale implementation.

The research done within AQUACONNECT will provide important scientific insight and technological and nature based solutions in possibilities and needs for further purification of wastewater, in order to return it responsively to the regional groundwater system. Besides the scientific challenges, utilization possibilities and governance issues are important drivers. Therefore, we are interested in and will commit our self to the research, with an in-kind contribution of € 6592,-. We intend to contribute as in-kind contribution in men hours, contributing to the case studies on the Higher Sandy Soils as follows:

- Integrating the scientific results in relevant fresh water provision concepts for the region,
- Share our experience with governance issues with the AquaConnect consortium
- Translating the scientific results to our own company and our network of industrial partners.

Description	Number	Cost price/tariff	Total
Senior specialist water treatment	*32*	*103*	*€3296*
Manager sustainability	*32*	*103*	*€3296*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

M. Junggeburth

Manager Sustainability Swinkels Family Brewers

Gemeente Terneuzen

Postadres: Postbus 35, 4530 AA Terneuzen
Bezoekadres: Stadhuisplein 1, 4531 GZ Terneuzen
Telefoon 14 0115
Vanuit buitenland: +31 115 455 000
E-mail: gemeente@terneuzen.nl
Internet: www.terneuzen.nl

Bij beantwoording a.u.b. onderwerp, datum en kenmerk van deze brief vermelden.

Prof. dr. ir Huub H.M Rijnaarts
Environmental Technology
Dep. of Agrotechnology & Food Sciences
Wageningen University Research Centre
P.O. Box 17, 6700 AA Wageningen

zaaknummer : 182143 /vh156686
contactpersoon : J. Groeneveld-Verdonk
telefoon : 14 0115
e-mail : j.groeneveld@terneuzen.nl
verzonden : 10 AUG 2020

Terneuzen, 10 August 2020

Onderwerp: Robust Watersystem participation to Aqua connect

Dear professor Rijnaarts,

The municipality of Terneuzen has 55.000 inhabitants, a large industrial area among the harbor and the canal from Ghent to Terneuzen as well as agricultural surroundings. The Belgian border and the Westerscheldt form our boundaries in Zeeuws-Vlaanderen.

The municipality of Terneuzen finds it important to create sustainable ways of using resources such as water. In our region, 100 million m³ of fresh water is discharged to the river Scheldt annually. About 50% of the volume originates from Flanders and is channelled and pumped through our municipality Terneuzen in Zeeuws-Vlaanderen. The overall water quality might be feasible for reuse. During summer periods both industry and agriculture suffer from a scarcity in fresh water supply. Therefore alternative sources of water with sufficient quality are being explored.

Since several years we are searching together for innovative ways to create sustainable use of water, less energy waste and environmental chances for urban and rural development under the steering group of the Robust Water system Zeeuws-Vlaanderen. Several goals are embraced by all the partners to optimise the whole water system robust, future proof and climate adapting.

We strongly believe that the coproduction between the involved partners such as Dow, HZ University of applied sciences, Evides, ZLTO, Water Board, province of Zeeland and our municipality have all chances to succeed and we want invest in further knowledge. The AquaConnect program will greatly facilitate new steps into this development in towards a sustainable water provision, and the results will be well received and used in further implementation.

As municipality we specifically aim for:

- The development and support for technical possibilities for making water reusable for industrial water supply for Dow and possibly other industrial plants as well as for agricultural and natural use.

- We are looking for enough water buffering to have the capacity to be able to supply agricultural and other users with the available fresh water within the region.

Logo Terneuzen to be used by Aqua Connect

Buffering can be established above or below surface or can be possibly combined by development of nature or use of other crops in agriculture.

- Multifunctional use of existing water loops as canals, rivers, creeks and streams, in which cross - border possibilities are surely very important in this region. We use the possibilities for landscaping and recreational use as well as nature development and incorporate them in our regional planning.
- Stimulating circular water use on micro and macro levels in urban areas as well as at the country site.
- Organisation of public interest and civil participation in reaching our goals for sustainable water use and climate adaption.
- Participation in scientific cooperation, that way gaining knowledge and creating possibilities for realization.
- Juridical translation and innovation in legalisation for town and country planning and other local and regional laws and Implementation in Strategic Planning.

We are willing to participate in the project by co- financing the coming 4 years by an amount of €10.000 cash and will invest yearly around 60 hours which means approximately €6200,- in kind.

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

undersigned, Jan A.H. Lonink, in the capacity of Mayor of the Municipality of Terneuzen

With kind regards,

Mayor of the Municipality of Terneuzen Town clerk

J.A.H. (Jan) Lonink J.G. (Jan) Princen

waterschap vallei en veluwe

UW WATERSCHAP

Adres Steenbokstraat 10
Postbus 4142
7320 AC Apeldoorn
Telefoon (055) 527 29 11
E-Mail info@vallei-veluwe.nl
Website www.vallei-veluwe.nl

WUR Environmental Technology
T.a.v. de heer Prof H.M. Rijnaarts
Postbus 17
6700AA WAGENINGEN

Datum	2 september 2020	Contactpersoon	C.P. Petri
Uw kenmerk		E-mailadres	cpetri@vallei-veluwe.nl
Ons kenmerk	1484749-1484757	Telefoonnummer	06 53910456

Onderwerp Support letter Aquaconnect

Dear professor Rijnaarts,

Waterschap Vallei en Veluwe is responsible for surface water quality and quality in our region as well as for flood protection and waste water treatment. We highly appreciate the integral approach of Aquaconnect.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions the allow full-scale implementation of the smart water-grid. Waterschap Vallei en Veluwe acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 10.000,- and an in-cash contribution of € 20.000,-.

The in-kind contribution consists of

- Further defining relevant scientific research questions during the first phase of AquaConnect
- Exchange of data and expertise with AquaConnect researchers
- Connecting AquaConnect to ongoing research initiatives on cyclic water systems of Waterschap Vallei en Veluwe
- Defining possible locations for demonstration of water-grids developed in AquaConnect

Bijlage(n) -

Description	Number	Cost price/tariff	Total
Senior policy advisor	*97 h*	*103*	*10.000*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Met vriendelijke groet,

Henry van Veldhuizen
Programma manager Wonen en Zuiveren

Bijlage(n) -

Vitens

Environmental Technology
Dep. of Agrotechnology & Food Sciences
Wageningen University Research Centre

Attn. Prof. dr. ir Huub H.M Rijnaarts
Bornse Weilanden 9
6708 WG WAGENINGEN

Behandeld door	Jan Gooijer	Datum	August 25, 2020
Doorkiesnummer	06-10644514	Email	jan.gooijer@vitens.nl
Ons kenmerk		Uw kenmerk	
Onderwerp	AquaConnect – Supportletter Vitens		

Dear professor Rijnaarts,

Vitens is the largest drinking water utility in the Netherlands, serving about 5,6 million customers on a daily basis. As a result of dry summers, increased water consumption by customers and companies and increased pressure on our groundwater sources, Vitens is looking for new solutions to produce drinking water. Water production from surface water, brackish water or even wastewater sources becomes increasingly necessary. To enable this, we need more knowledge on topics like membranes and brine management. This is where AquaConnect provides necessary knowledge.

Vitens will contribute to AquaConnect with an in-cash contribution of €90.000,- and an in-kind contribution of €93.137,- (table 1) Based on discussions with the relevant researchers, we will contribute cash and in kind to workpackage 3 and workpackage 4.

WP3: we will contribute €65.000,- in cash. We will contribute €83.146,- in kind mainly in lab analysis to support the development of new risk-assessment strategies for cyclic water systems. The maximum in kind contribution annually is €20.000,- in lab analysis. We will also provide a research location that can be used for the in-situ determination of the formation of transformation products of contaminants of emerging concern in aquifers.

WP4: we will contribute €25.000,- in cash. We will contribute €9991,- in-kind to subproject 1 in human hours of in-house water treatment specialists to support the development of electrodialysis/nanofiltration combinations for fit-for-purpose water treatment.

Oude Veerweg 1, 8019 BE Zwolle. Postbus 1205, 8001 BE Zwolle
T 088-884 88 88 F 088-884 67 99 KvK Zwolle 050.69.581

www.vitens.nl

Our reference
Date August 25, 2020

Table 1. Specification of in-kind support

Description	Number	Cost price/tariff	Total
Specialist Water Treatment	*97 h*	*103 €/h*	*€ 9991,-*
Labanalysis - Chlorophenols	*50*	*€ 300,01,-*	*€ 15000.51*
Labanalysis – Volatile aromatic hydrocarbons	*50*	*€ 89,68*	*€ 4484,22*
Labanalysis – Glyphosate, AMPA, Glufosiaat	*50*	*€ 102,77*	*€ 5138,56*
Labanalysis – Basic OC20	*50*	*€ 128,92*	*€ 6445,87*
Labanalysis – Basic Pesticides	*50*	*€ 258,43*	*€ 12921,26*
Labanalysis – Basic polar priority-compounds	*50*	*€ 386,21*	*€ 19310,56*
Labanalysis – Chloridazon & metabolites	*50*	*€ 67,13*	*€ 3356,56*
Labanalysis – Basic anthropogenic target compounds	*50*	*€ 173,20*	*€ 8659,78*
Labanalysis – Fungicides and herbicides	*50*	*€ 156,58*	*€ 7828,86*

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Kind Regards,

Rik Thijssen
Manager Business Development

Vitens

Vitens N.V. | Oude Veerweg 1 | Zwolle | Postbus 1205 | 8001 BE Zwolle

stichting wateralliance P.O. Box 7560, 8903 JN Leeuwarden, The Netherlands visitoraddress Agora 4, 8934CJ Leeuwarden
phone 0031 (0)58 284 90 44 email info@wateralliance.nl kvk 01169665 btw NL821701241B01 iban NL82 RABO 0153 4401 63 bic RABONL2U

Leeuwarden, 28-07-2020
Subject: Support letter

Dear professor Rijnaarts,

Water Alliance (WA) is a unique partnership (110 members) of public and private companies, government agencies and knowledge institutes involved in the Dutch water technology sector. WA is the network organisation for the Dutch water technology sector and focuses on innovative and sustainable water technology that can be used worldwide. WA supports small and medium sized enterprises in the water technology industry in terms of (international) matchmaking, networking and business development. Its core activities are: International and national branding and lobby, international and cross-sectoral matchmaking, organising and coordinating incoming missions and outgoing visits, organising and coordinating (international) events and in-depth business development advice for innovative water technology SMEs.

Furthermore, WA is one of the three managing partners of WaterCampus Leeuwarden, the physical core of the Dutch water technology sector. WaterCampus Leeuwarden stimulates cooperation between (inter)national businesses, knowledge institutes and governments within the water technology sector, in order to create synergy for world class innovation, education and entrepreneurship. This innovation ecosystem brings together the complete chain of innovation for water technologies, from idea to market. In this way we help companies to find the best way through the innovation chain to cover their needs and speed up their developments.

AquaConnect provides solutions for regional water provision problems by developing integrated smart water-grids based on innovative digital and chemical technologies that enable circular approaches for fit-for-purpose and on-demand fresh water supply based on currently unexploited water resources. Demonstration of these smart water-grids will occur in different regions of The Netherlands and internationally, and is accompanied by a scientific assessment of the financial, economic, legal and political conditions that allow full-scale implementation of the smart water-grid. Water Alliance acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 25.890,-. The in-kind contribution is dedicated to support AquaConnect on its pathway to societal impact and to connect Dutch water technology companies to AquaConnect. The support consists of:

- Functioning as an intermediary between the companies united in AquaConnect and companies connected to the Water Alliance with the aim to create new partnerships in the demonstration and valorization phase based on key technology development and new concepts for circular water management.

stichting wateralliance P.O. Box 7560, 8903 JN Leeuwarden, The Netherlands visitingaddress Agora 4, 8934CJ Leeuwarden
phone 0031 (0)58 284 90 44 email info@wateralliance.nl kvk 01169665 btw NL821701241B01 iban NL82 RABO 0153 4401 63 bic RABONL2U

- Supporting AquaConnect in national and international outreach by co-organizing network events for consortium-partners and external parties. For example during Water Alliance events (WaterLink, European Water Technology Week, etc.).
- Advising AquaConnect on the dissemination of scientific results towards implementation in the case-studies, and thereby on its pathway to impact.
- Connecting the small scale technology developers in AquaConnect to the incubator at WaterCampus Leeuwarden to support their valorization/innovation acceleration.

Description	Number	Cost price/tariff	Total
André Mepschen Business Developer Nationaal	60	103	6.180
Ronald Wielinga Manager Entrepreneurship	150	103	15.450
Stefan Bergsma International project coordinator	60	71	4.260
			25.890

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Hein Molenkamp, Managing director

Wageningen University Research Centre
Environmental Technology
De heer Prof. dr. ir H.M Rijnaarts
Postbus 17
6700 AA WAGENINGEN

Verzenddatum:	16 JULI 2020
Nummer:	
Uw brief van:	
Uw kenmerk:	
Onderwerp:	Participation Aquaconnect
Projectnummer:	
Contactpersoon:	ir. A.M. Kramer-Hoenderboom
Telefoon:	+31652600953
E-mail:	a.kramer@wrij.nl
Kopie aan:	Auteur, masc, ntam, wolt
Bijlage(n):	

Geachte heer Rijnaarts,

Waterboard Rijn en IJssel takes care of water in the eastern part of the Netherlands by: regional water management, wastewater treatment and flood protection (https://www.wrij.nl/thema/algemeen-praktisch/landingspagina/). Over the last 3 summers the region experiences the effects of extreme dry summers. Therefore the waterboard is developing a new strategy on water management/provision, to be able to cope with these dry periods. Re-use of treated wastewater is one of the water sources that is taken into account. AquaConnect will bring us necessary knowledge and experience for developing and implementing our new strategy.

Waterboard Rijn en IJssel acknowledges the importance of finding solutions for regional water provision problems and commits itself to the research performed in AquaConnect with an in-kind contribution of € 25.000,- and an in-cash contribution of € 25.000,- (€5.000 per year). The in-cash contribution is dedicated to support the research connected to the Sandy Soils, of which Waterboard Rijn en IJssel is part. Knowledge-development in the fields of digital technologies (WP2), chemical technologies and risk-assessment (WP3) and water governance (WP4) are of equally great importance for Waterboard Rijn en IJssel. The in-kind contribution is dedicated to improving the connection between the scientific research and the case-studies, both during the initial phase of the program (€ 10.000,- in hours), and during the realization of impact in the final stage of the program (€ 15.000,- in hours). The in-kind contribution consists of:

- Information exchange about the implementation of regional relevant cases within the AquaConnect framework
- Information exchange about innovative projects of the waterboard related to waste water management, with a specific emphasis on the reuse of wastewater-treatment effluent and its connection with potential users

See the table below for a specification of the in-kind support:

Bezoekadres: Liemersweg 2, 7006 GG Doetinchem | **Postadres:** Postbus 148, 7000 AC Doetinchem
Tel.: 0314-369 369 | **Fax:** 0314-343 258 | **E-mail:** waterschap@wrij.nl | **Internet:** www.wrij.nl | **Bank:** 63.67.57.331

Swiftadres: NWABNL2G | **IBAN:** NL68 NWAB 06367573 31 | **BTW nummer:** NL 805432759B01 | **KvK** 09212548

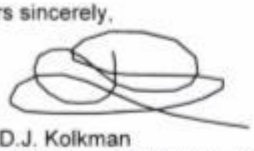
Description	Number	Cost price/tariff	Total	Percentage that can be attributed to the project
Regional relevant case (initial stage):				
policymaker waste water treatment	43	116	5000	100% WP5
policymaker surface and ground water	43	116	5000	100% WP5
Regional relevant case (final stage):				
policymaker waste water treatment	65	116	7500	100% WP5
policymaker surface and ground water	65	116	7500	100% WP5

Furthermore Waterboard Rijn en IJssel intends to give in consideration an additional contribution from the innovation program of the Waterkracht waterboards. However, this requires more time within the decision-making process of Waterkracht.

Obligatory paragraph by NWO:
We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Yours sincerely,



drs. D.J. Kolkman
manager Zuiveringsbeheer en Riolering

Witteveen + Bos

Wageningen UR
att: prof.dr.ir. H. Rijnaarts
Bornse Weilanden 9
6708WG Wageningen

Date	14 July 2020
Your reference	AquaConnect NWO-TTW
Reference	117879-7
Handled by	dr.ir. A.F. van Nieuwenhuijzen
Telephone / e-mail	06 53 92 50 56 / arjen.van.nieuwenhuijzen@witteveenbos.com
Subject	Support AquaConnect

Dear professor Rijnaarts,

Hereby I declare on behalf of Witteveen+Bos that we will support the NWO-TTW Perspectief project P19-45 AQUACONNECT - Climate robust water provision and management for delta regions as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html based on the activities and topics as described in the July 9, 2020 Phase 3 Project description.

As Witteveen+Bos, we have taken notice of the conditions for the NWO-TTW-Perspectief call and have been informed about your application in this call. We are very interested in participating in this research programme, focussing on the Demo Sandy soils and the Demo Fresh Water Challenges Amsterdam Metropolitan Area and North-Holland.

Introduction of Witteveen+Bos
Witteveen+Bos is a company based in the Netherlands that provides consultancy and engineering services worldwide in the fields of infrastructure, water, the environment, spatial development and construction. Our multidisciplinary approach to projects is the distinctive feature of the way we work. Witteveen+Bos is involved in projects around the world to plan and design the urbanisation of the coming decades. Sustainable development necessitates interaction between the spatial development and environmental disciplines. Witteveen+Bos's specialists in spatial development and environmental issues make a pivotal contribution through their ability and willingness to look beyond the fences of their own domains. Our activities range from working in distinct fields to assuming integral responsibility, but without losing sight of interfaces with other disciplines. Our overarching approach produces numerous benefits through close cooperation between experts from different parts of our firm: + Drinking water; + Used water treatment; + Industrial water; + Water management; + Circular Resources Recovery.

Date 14 July 2020
Reference 117879-7

Description of support
We are interested in participation in the project, because the integrated approach and focus of the project - the development of innovative integrated solutions based on new physical and societal connections enabling innovative circular approaches, in which two key enabling technology categories -digital and chemical technologies- are combined with innovative water management solutions. Especially drought salinity related solutions are of interest to us since this affects our daily working practice. As the program enables the development of new digital and chemical technologies and combination in a smart water-grid to use the subsurface as a water battery for storing surplus water and balance the yearly demand of high quality fresh water this fits perfectly. These new technologies need to be developed in a co-creative process between universities, engineering companies, consultants and technology-suppliers, and will be demonstrated in four different case-studies in The Netherlands. The demonstration of these technologies will be facilitated by close cooperation with research institutes, regional authorities, waterboards, drinking water companies and water users. Scientific analysis of the socio-economic and legal aspects underlying the successful implementation of the new digital and chemical technologies in a smart water-grid will form the basis of successful business-cases, that can be scaled up to the whole Netherlands, and internationally, which is important for our business development

Besides the scientific challenges, especially the utilisation possibilities of the deliverables of the project are important drivers for our participation.

We will contribute with EUR 7.500 per year in cash for being able to participate to the total project, especially the Sandy Soil and MRA Demo cases, and be part of the steering committee, totalling to a maximum of EUR 30.000,-- over 4 years of the project duration.

Furthermore we provide an in-kind contribution of a total of a maximum of EUR 25.132,-- as specified below:

Table 1 In kind contribution

activity	estimated time (hr)	tariff[1] (EUR/hr)	costs (EUR)
Providing insights in freshwater concepts like Waterfabriek	32	103	3.296
System integration and high level cost calculations for proposed solutions Sandy Soils demo case and MRA demo case	60	103	6.180
Stakeholder management and Quality Assurance	40	103	4.120
Value case development for Sandy Soils demo case and MRA demo case	40	103	4.120
Attending and participating in Sandy Soils demo case and MRA demo case related workshops	48	103	4.944
Steering committee	24	103	2.472
TOTAL			25.132

[1] Maximised by NWO to EUR103/hr

Date 14 July 2020
Reference 117879-7

Yours sincerely,

Arjen Frans van Nieuwenhuijzen

Digitally signed by Arjen Frans van Nieuwenhuijzen
Date: 2020.07.14 22:17:33 +02'00'

dr.ir. A.F. van Nieuwenhuijzen
project director

Enclosure(s)

Copy

NETHERLANDS
WATER PARTNERSHIP

Wageningen University & Research
Sub-dept. of Environmental Technology
Prof. Dr. Ir. H.H.M. Rijnaarts
P.O. Box 17
6700 AA WAGENINGEN

Subject: Supportletter
Our ref: 2020-034
Date: The Hague, 7 September 2020

Dear professor Rijnaarts,

The Netherlands Water Partnership is a network of Dutch organizations in the water sector with international ambitions. NWP's members include companies, government agencies, knowledge institutions and NGOs with one common goal - to join forces for sustainable water solutions worldwide. Adept at matchmaking, NWP is the first point of call for anyone seeking expertise on water management issues or contact with the Dutch water sector. Given its wide and growing network, NWP is also the first point of call for its members in the Netherlands who are seeking expertise and partnerships internationally.

Based on this mandate to be a connector in the Dutch Water Sector and to be a catalyst for collaboration amongst academic, public and private water sector parties – both members and non-members, we see great potential in the Aqua Connect program. We are triggered by all the objectives of the Aqua Connect, but see a specific role for NWP in the areas of social and climate scenario simulations, use of digital technologies to identify and verify existing water resources and the possibilities for freshwater management, with a particular focus on surface and groundwater interactions.

As such, NWP, hereby commits itself to the Aqua Connect program, under the auspices of the NWO-domain TTO. NWP commits to an in-kind contribution of 60 hours / year for the 5-year duration of the program in support of the Aqua Connect initiative.

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NETHERLANDS
WATER PARTNERSHIP

Description	Number	Cost price/tariff	Total
Project Manager	*100*	*103*	*10300*
Project Officer	*200*	*71*	*14200*
TOTAL	*300*		*24500*

Coordination and involvement for this project within NWP, will be through Arjan Braamskamp, a.braamskamp@nwp.nl, 06 82944161

We have read and have been fully informed about the application. We state that we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation.

Furthermore, we are aware that the abovementioned project is part of a NWO Domain TTW Perspectief programme.

Kind regards,

B.S.J. Nijhof
Managing Director

Ministerie van Infrastructuur en Waterstaat

To:
prof. dr. ir. H.H.M. Rijnaarts
Wageningen UR
Bornse Weilanden 9
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Datum
7 september 2020

Kenmerk
IENW/BSK-2020/173961

Subject: Letter of support AquaConnect

Dear prof Rijnaarts,

With this letter I declare on behalf of the Ministry of Infrastructure and Water Management our interest in and support for your NWO-TTW Perspective project P19-45 AquaConnect - Climate robust water provision and management for delta regions.

We have read and have been informed about your application as described on www.nwo.nl/en/research-and-results/programmes/ttw/perspectief/2019-2020-p19-45.html and in greater detail in the proposal and are interested in participating in this research programme.

The topics addressed in AquaConnect are urgent and of the highest societal importance. With almost half the country situated below sea-level The Netherlands is vulnerable to climate change causing further rise in sea level, creeping processes of salinization, dry summers, declining ground water levels and as a consequence increasing risks for land subsidence. More and more we have to deal with whether extremes and fluctuations in both river discharges flowing through our delta and in ground water levels.

Via, among other things, the Delta Program the government has charted ambitious policy goals for the future in terms of water supply and demand, and we have entered into innovative forms of collaborations with residents, businesses, knowledge institutes, universities and NGOs, under the umbrella of the National Water Plan. Water availability is becoming one of the major societal challenges that the Netherlands are facing. A reliable and robust water management system requires innovative and cost-effective measures to maintain required and highly necessary water levels for shipping, sufficient water resources for agriculture, energy production and industry, but also for drinking water production. Water is an essential resource for our economy, and therefore threatening shortages urgently need to be addressed by bringing into play new technologies that will help us enhance water availability, by widening

the scope of water resources, providing for more efficient use, storage and re-use of water.

New technologies need proof of concept, need to be approved by authorities and endorsed by economic actors. This requires both adaptation with respect to culture and governance, financial instruments and water management and they need to be upscaled at home and exported abroad. As Ministry, we believe that the AquaConnect proposal can and will play an important role in each of these processes and that the Ministry can play a role in this adaptation. Having participated in some of the underlying programs like WaterNexus, COASTAR, Lumbricus and KLIMAP, the Ministry acknowledges the economic needs that AquaConnect will address. We see added value and an urgency to invest in the AquaConnect program, which will address issues of major concern in some of the top economic areas in the country, including Amsterdam, Rotterdam, the Westland, the high sandy soils in the East and South of the country.

The AquaConnect research will deliver actionable knowledge on both digital and chemical technologies that will help water availability at societally desirable levels and novel governance strategies that will allow their rapid uptake. It is expected to extend the range of water supply sources available.
With our support we would in particular contribute to research and activities dealing with governmental issues and the international outreach.

Description of support
As a result, the Ministry of Infrastructure and Water Management confirms we will contribute the AquaConnect program financially with an in-cash contribution of 100.000,- euros (5 x 20.000,- euros for the years 2021 up to and including 2025) inclusive Dutch VAT. This amount will be paid to the NWO if the application is granted.

In addition we will actively participate in the User Committee (UC) established and that we will comply with the applicable terms and conditions for participation. Furthermore, we are aware that the abovementioned project is part of the NWO Domain TTW Perspectief programme.

Yours sincerely,

Elisabeth H.S. van Duin PhD MSc

Director Water, Soil and Marine
Ministry of Infrastructure and Watermanagement

Waterschap Scheldestromen

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	(bij reactie graag dit nummer vermelden)	verzenddatum	: 3 september 2020
bijlagen	:	projectnummer	:

onderwerp : Steunbrief AquaConnect

Middelburg, 2 september 2020

Geachte heer Rijnaarts,

Wij hebben uw verzoek ontvangen ten behoeve van het onderzoeksprogramma AquaConnect, welke deel uitmaakt van een NOW Domein TTW Perspectief programma. Vanwege strategische toekomstige ontwikkelingen zijn we verheugd over de intentie om dit onderzoeksprogramma op te starten.

Waterschap Scheldestromen beheert het oppevlaktewatersysteem in een deel van Nederland waar veel gebieden zijn waar geen zoet water aangevoerd kan worden en waar vooral brak water aanwezig is. Door de droge jaren 2018 en 2019 is de vraag naar structureel zoet water groot en is Scheldestromen betrokken bij diverse zoetwaterinitiatieven.

Wij willen de samenwerking graag aangaan en reserveren € 60.000,-- ten behoeve van de cofinanciering aan het 4 jaar durende onderzoeksprogramma AquaConnect voor het doen van onderzoek naar een Robuust Watersysteem in Zeeuws-Vlaanderen. Daarnaast zijn we bereid 40 uur te investeren, wat neerkomt op ongeveer € 5.000,-- in natura per jaar.

Hopende u hiermee voldoende geïnformeerd te hebben.

Hoogachtend,

namens het dagelijks bestuur
van waterschap Scheldestromen

J.F.C. de Brouwer
programmamanager Watersystemen

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