Center for Advanced Water Research

Integrated Water Resources Management in the Context of Global Change

A strategic cooperation between the Helmholtz Centre for Environmental Research - UFZ and the Dresden University of Technology (TUD)

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

CAWR
Center for Advanced Water Research

TECHNISCHE UNIVERSITÄT DRESDEN

Contents

Preamble

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Water is increasingly becoming the focus of international debates. Whether it is food or energy security, human health and ecosystems, flood defence and droughts, or the provision of drinking water or sanitation systems: water is a crucial topic for a sustainable society – whether here in Germany, in Europe or worldwide.

The Center for Advanced Water Research has been established in an attempt to react to these challenges, by coming up with a holistic response, as complex challenges cannot be overcome with single solutions. Hand in hand with the most important partners in the field of water research and sustainable development we will make our scientific competences available to strategically develop training and successfully transfer our competences to practice, policy-making and society both at the national and international level.

Water is a core research focus both at the TU Dresden and at the UFZ. For a long time now we have benefited from successful cooperation within national and international projects, through training as well as from setting up the Water Science Alliance together – the alliance of the German water research community. We have strengthened our competences in this field over recent years and invested in strategic development.

The foundations for cutting-edge water research have been laid with the initiation of the Water Science Alliance by the UFZ, the chairmanship of which is currently held by the TUD, and the establishment of the Helmholtz Water Network with the TUD as a key partner of the UFZ. With the Center for Advanced Water Research, the region Dresden-Leipzig-Magdeburg-Halle is emerging as an international pivotal point for water research.

Water builds bridges. In the future, the Center for Advanced Water Research will be a strong international partner in the fields of research, training and transfer towards securing our water resources. And consequently we will contribute to a sustainable future for our society – both here in Germany and worldwide!

We look forward to a fruitful cooperation,

1. The need for research and development in the water sector

Fig. 1: Sustaining food, energy and water supplies requires a sustainable management of our water and soil resources.

GLOBAL & SOCIETAL CHALLENGES

All over the world, water resources are under increasing pressure from global change: population growth, climate change, land-use changes and the associated degradation of soil, increased urbanisation, industrialisation and economic changes all impact the quality and quantity of our water resources. Due to the complexity of such change processes, different interactions between various factors and unpredictable political and societal reactions to imminent environmental changes, even science can still not answer the question as to how a world population of 9 billion people will be fed and supplied with clean drinking water in the year 2050.

Due to longer lasting periods of drought and increased risks of floods, climate change will also influence the spatio-temporal distribution of water resources in the future. In addition to water, the keys to ensuring human health and food security for the world population are intact soils and appropriate land-use systems, well-designed irrigation technologies and functional sanitation systems.

Because of changes to the distribution and quality of water resources, a forward-looking and integrated management of water, land, soil and energy resources, that is based on reliable scientific findings will increasingly influence the health and wealth of the world population.

SCIENTIFIC CHALLENGES

Fig. 2: 70 % of the Earth's surface is covered by water. 97% of the water on Earth is saline water and only 3% is freshwater. Most of this freshwater is stored as ice in polar caps and glaciers or as groundwater. Less than 0.5% of the entire water resources on Earth are available for human use and terrestrial ecosystems.

The scientific challenges associated with sustainable water resources management involve the natural, social and engineering sciences. To understand the environment in all its complexity and its interactions with technological interventions, a systemic approach is necessary that extends well beyond disciplinary perspectives.

Coming up with realistic scenarios of important human-environment interactions on various spatio-temporal scales requires the development of complex model systems. With the help of these feasible options for courses of action can be identified that adapt to new or increased risks, and measures for the long-term security of water resources can be devised.

Such options should be based on investigations of the environmental system as well as on socio-economic analyses. Institutional frameworks in particular have to be taken into account, as they considerably influence the behaviour of stakeholders, as well as the success of implementing measures and concepts. Finally, system-relevant solutions should be developed considering the interplay between technological, natural, economic and social potential.

STRUCTURAL REQUIREMENTS

The development of innovative technologies and strategic solutions extending well beyond any previous approaches and methods requires a realistic assessment of future conditions and requirements, in order to identify timely opportunities and potential.

So far the international research arena is not in the position for this. Strong fragmentation or too much focus on disciplines, particularly in Germany has indeed led to a strong specialisation and diversity; however what is required is a targeted consolidation of competences through a strategic cooperation that extends well beyond sectors or institutional borders. Only in this way global challenges in the water sector can be met. A strong cooperation between science and practice, policy-making and management is essential for achieving future requirements.

The Center for Advanced Water Research unites research, training and transfer for Integrated Water Resources Management under global change.

Fig. 3: Rappbode drinking water reservoir.

2. Background: Water research within the Helmholtz Association and in German universities

An investigation commissioned by the Federal Ministry for Education and Research (BMBF) since 2010 on water research in Germany clearly shows that when combined there is considerable research competence and capacity available in German universities and non-university research institutions. The research arena overall however remains very diffuse, with a lack of thematic focus in cross-institutional cooperation. From a structural perspective there also appears to be a need for long-term arrangements set out at the national and federal state level.

As a reaction to the global challenges in the water sector, the Water Science Alliance was initiated in Germany in 2010. The alliance is an open platform for the interdisciplinary water research community that promotes cooperation extending beyond institutional and disciplinary borders to tackle the challenges in the water field. The „water field" covers all water-related disciplines ranging from hydro(geo)logy, meteorology, limnology, soil sciences, engineering disciplines, social- and political sciences as well as economics.

The mandate to develop the concept of the Water Science Alliance was given to the Helmholtz Center for Environmental Research – UFZ that coordinated the set-up process of the Water Science Alliance, which was then carried over to the DFG-KOWA (Senate Commission on Water Research of the German Research Foundation). Finally, the Water Science Alliance e.V. (chairmanship: TUD) was established as the community platform with the inaugural meeting taking place on 26th February 2013.

Within the framework of setting up the Water Science Alliance, 6 priority research fields („grand challenges") were initially formulated in the so-called White Paper. These research topics are to be jointly tackled in thematic clusters consisting of partners from universities and non-university research institutions. Here the senate commission on water research of the German Research Foundation (DFG-KOWA) plays a pivotal role in establishing the Water Science Alliance as a community platform.

The Helmholtz Association reacted to the major challenges facing water research outlined in the White Paper of the Water Science Alliance and to the fragmentation that was highlighted by the investigation on the water research landscape and procured funding accordingly (PAKT II, „portfolio funds"), from which the „Helmholtz Water Network" was developed (coordinated by the UFZ). This laid some of the initial foundations required for setting up work structures to address the major challenges in water research through a joint effort. Complementary competences are pooled from the participating Helmholtz centers in close cooperation with the universities. Besides the cooperation between the UFZ and the TUD (research field: „Integrated Water Resources Management") within the Helmholtz Water Network, the university cluster Tübingen - Hohenheim - Stuttgart is the UFZ's second main university partner (research field: „Water and matter fluxes at catchment scale").

Building on the unique concentration of water research disciplines and a long tradition of hydrological sciences in Dresden, the TUD has (within the framework of the national excellence initiative) defined water research as a research focus at the University. The cross-linking of a number of relevant disciplines within the Faculty for Environmental Sciences and beyond (incl. the Faculty for Civil Engineering and the Faculty for Economics) creates unique potential. A new impulse was given for further trans-disciplinary networks and the internationalisation of the TUD, when the FLORES Institute of the UN University was founded in Dresden with its research focus „water-soil-waste nexus".

There is a very close cooperation between the UNU-FLORES and the TUD (mainly with the Faculty for Environmental Sciences). Furthermore, the TUD hosts the UNEP/UNESCO/BMU postgraduate course „Environmental Management", the only one of its kind in the world and on offer for 35 years in cooperation with the Federal Ministry for the Environment and the United Nations (UNEP Nairobi and UNESCO Paris). At CIPSEM, specialists and managers from developing and emerging countries receive consolidated training, particularly in the field of water research. Over the years, this institution for knowledge transfer has been able to set up an impressive international Alumni network.

Within the framework of the Water Science Alliance as well as in the national and European water research community, the competences of the TUD and the UFZ represent a unique concentration of competences available in the water research field and particularly on the topic of Integrated Water Resources Management. Based on the number of scientists in the water field, the UFZ and the TUD are among the largest institutions in Germany working in water research. By setting up the Center for Advanced Water Research, they will be one of the largest international actors in the water research sector by European standards (see Fig. 5a and 5b).

Fig. 4: River Saale flowing into the river Elbe

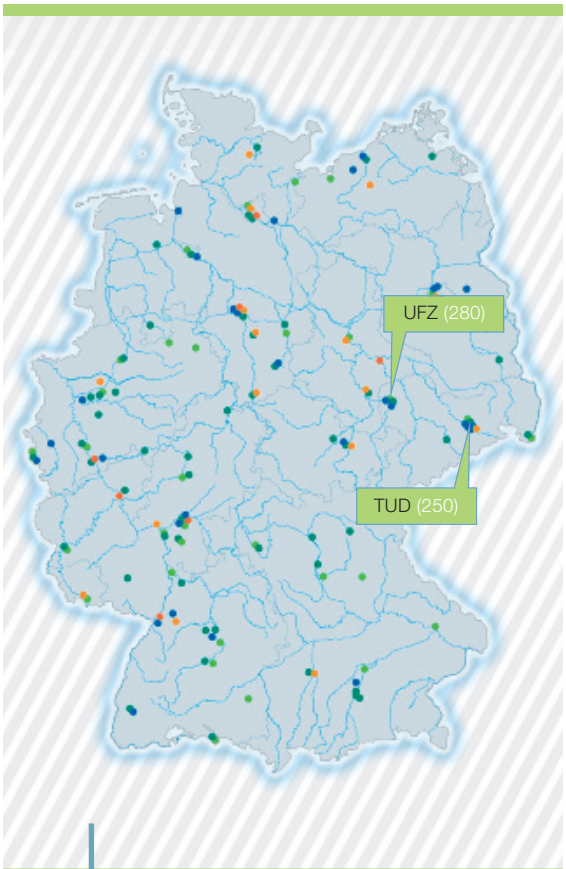

Fig. 5a: Publicly-funded institutions in Germany with a focus on „water research". The TUD and the UFZ are highlighted. The number of scientists working in the field of water research is shown in brackets. Source: Analysis of water research in Germany. See also: www.watersciencealliance.org/online-portal

Fig. 5b: The 12 largest institutions in the „water research sector" in Europe by numbers of scientists in the water field.

3. The goals and concept of the Center for Advanced Water Research

The Center for Advanced Water Research will pool the competences from both the TUD and the UFZ in the water research field on a strategic level, and will work as a cluster similar to the two DFG-funded research clusters of the national excellence initiative at the TUD. At the CAWR, research goals will be jointly defined, scientific strategies determined and coordinated, academic staff appointed and trained according to jointly agreed strategies, and research infrastructures will be jointly run and maintained. This integrative partnership will drive new synergies promoting future-oriented, cutting-edge research on topics relevant to society in the water field. This will then serve as a basis for providing scientific advice to politicians, decision-makers and partners from industry, to implement new solutions and instruments in practice.

In the spirit of the Water Science Alliance, the Center for Advanced Water Research aims to contribute to overcoming the grand scientific, economic and societal challenges in the field of water research. At the interdisciplinary Center for Advanced Water Research, scientists from the natural sciences, engineering disciplines as well as economics and social sciences benefit from cross-institutional cooperation. The Center for Advanced Water Research focuses on „Integrated Water Resources Management in the context of Global Change“ (see „Thematic fields and structure of the Center for Advanced Water Research“). At the same time the international visibility of both the TUD and the UFZ and global research activities will be promoted. The platform uses the existing research infrastructure from both institutions (Terrestrial Environmental Observatories - TERENO, TERENO-MED (Mediterranean region), Integrated Carbon Observation System - ICOS) and uses close ties with organisations in the fields of transfer, practice and international cooperation (GIZ, GWP, KfW etc.) as well as in the field of training (UNU-FLORES, UNEP- CIPSEM, DAAD-networks, IHP etc.).

Establishing the Center for Advanced Water Research allows the potential to be used that emerges from the large number of scientists at both research institutions and the breadth of research topics covered: TUD (25 professors, ca. 250 scientists) and UFZ (23 professors, ca. 280 scientists; see Fig. 6a and 6b). From the active groups at both institutions in the field of water research half of them already contribute to the joint postgraduate school HIGRADE or work in joint projects. The International Water Research Alliance Saxony (IWAS) is an excellent example for the fruitful cooperation between UFZ and TUD. The main goal of IWAS is the development of solutions to global water problems and their implementation in different model regions in Eastern Europe (Ukraine), Central and Southeastern Asia (Mongolia and Vietnam) as well as Latin America (Brazil). The project, which was funded by the Federal Ministry of Education and Research (BMBF), was set up with the long-term objective establishing a joint water research center. The Center for Advanced Water Research unites the fields of water research from both institutions in the form of a strategic cooperation. This is a considerable contribution to the further invigoration of the cooperation that has existed since 2006 (cooperation framework agreement).

Center for Advanced Water Research

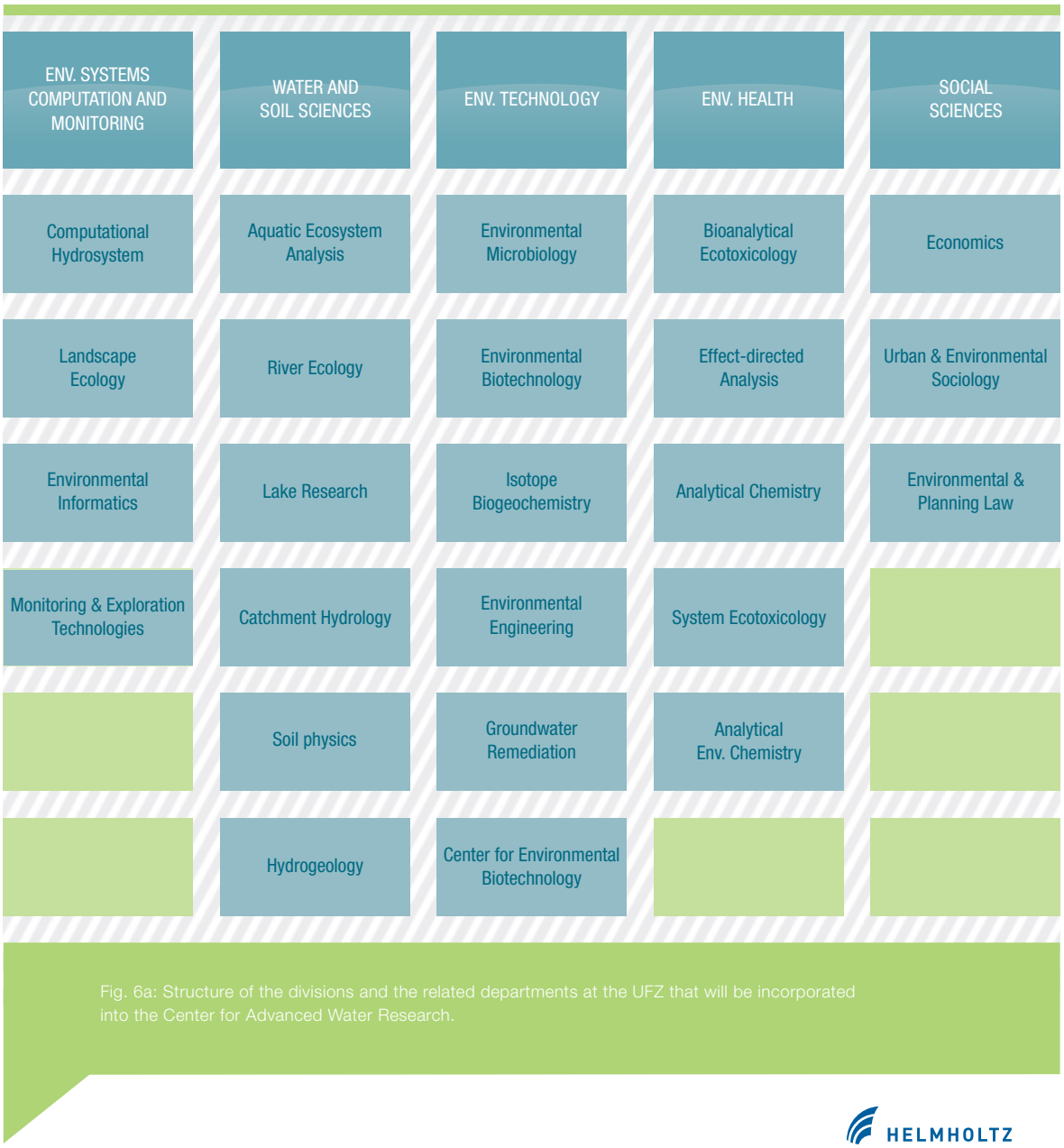

Fig. 6a: Structure of the divisions and the related departments at the UFZ that will be incorporated into the Center for Advanced Water Research.

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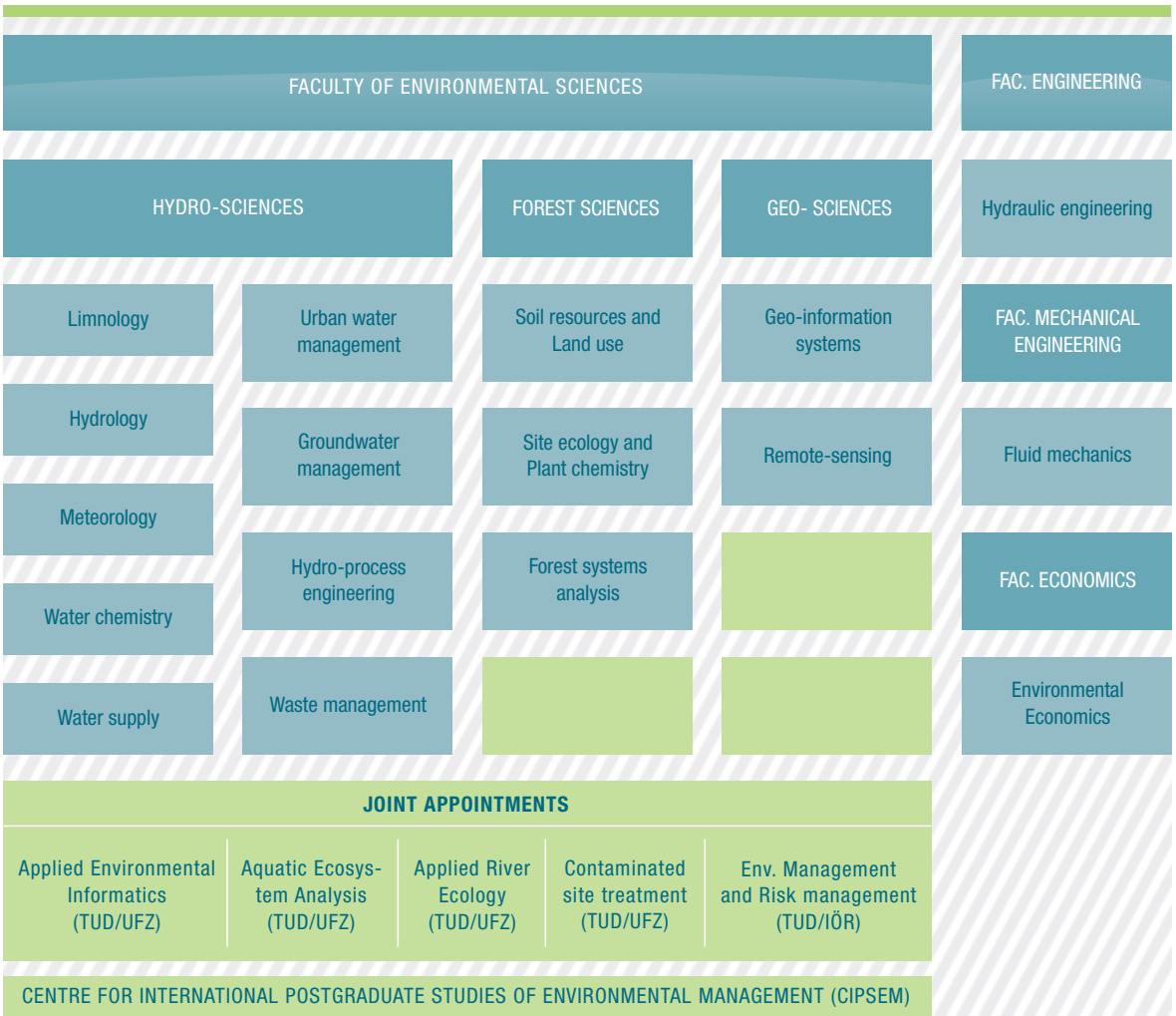

Fig. 6b: Structure of the Faculty of Environmental Sciences with the relevant professorships and the faculties of mechanical engineering and economics at the TUD. The professorships listed are currently part of the Center for Advanced Water Research.

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4. Thematic fields and structure of the Center for Advanced Water Research

Fig. 7: The three „pillars“ of the Center for Advanced Water Research

The Center for Advanced Water Research focuses its work on the fields of research, education & training and transfer

4.1 RESEARCH

The Center for Advanced Water Research primarily focuses on research and application in the field of “Integrated Water Resources Management in the context of global change”, incorporating the fields of water quality, wastewater management, water and food supply, soil and land use as well as human health. Consequently, research at the Center for Advanced Water Research will take into account the entire water cycle including chemical, bio-geochemical, evolutionary and ecological processes as well as their socio-economic conditions and implications.

The research work conducted ranges from fundamental to applied research. What really makes the center unique is the profound disciplinary expertise and at the same time the breadth of research topics covered by both institutions as well as their outstanding national and international networks.

The thematic profile of the Center for Advanced Water Research is based on six thematic fields:

1) Quality and dynamics of the water cycle
- Understanding processes: Water cycle and water quality

2) Water scarcity in the regional context
- Sustainable resources management in particular in water scarce catchments

3) Urban Water Resources Management
- Processes and dynamics of matter in the urban system

4) Methods of data collection and information processing
- Monitoring, modelling of processes and data

5) Societal and climate change
- Regional transformation strategies and scenarios

6) Water Governance
- Management targets, obstacles, strategies and instruments

THEMATIC FIELD 1
QUALITY AND DYNAMICS OF THE WATER CYCLE

Understanding processes: Water cycle and water quality

Securing high-quality water in sufficient quantity is one of the most imminent challenges in the context of global change so much so that the access to clean drinking water has now been given the status of a basic human right. In fact, since the millennium declaration, issues such as the provision of safe drinking water and hygienic wastewater systems have ranked high on the list of pressing global issues. The provision of high-quality water includes many aspects – not only the quality of drinking, bathing and process water but also sufficient water quality that will enable essential ecosystem processes to work and provide habitat to conserve aquatic biodiversity. In this respect, the water quality level will depend considerably on water volumes as well as flow paths and retention times in the catchment area (surface waters, soil water and groundwater), that influence matter-specific fluxes.

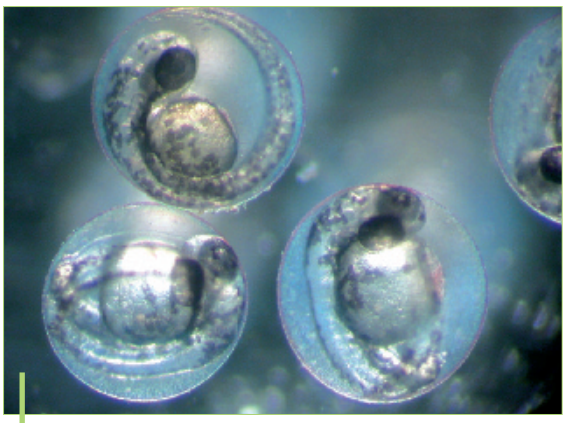

Fig.8: The development of organisms in our water bodies can be impaired by chemical pollutants.

The considered hazards should not be restricted to those present for some time now (including those with unsatisfactory solutions e.g. eutrophication or heavy metal pollutants), but also emerging and increasingly well-known hazards (e.g. neobiota, nano-particles, emerging pollutants or genetically-modified organisms such as antibiotic-resistant bacteria and increasing concentrations of dissolved organic carbon - DOC).

The Center for Advanced Water Research stands out due to its comprehensive competences for investigating how ecosystem processes, properties and matter fluxes are influenced or altered by emerging hazards and how ecosystems on the other hand have a catalytic effect on emerging hazardous pollutants.

With the complexity of hazardous substances and their input flows, it is becoming increasingly apparent that an „end-of-pipe“ water quality management, that purely focuses on technological solutions for controlling input flows into water bodies does not suffice. Rather, a sustainable water quality management should also take into account the behaviour and effect of stress factors in various systems of the water cycle (e.g. surface and groundwater ecosystems, sewage systems), as well as the dynamics of controlling hydrological processes. In this respect, a fundamental understanding of the processes is imperative.

Fig. 9: The Rappbode reservoir in the Harz Mountains serves as flood water protection as well as providing drinking water and energy production. Researchers have been investigating the dynamics of its water quality.

Finally, these topics also encompass social and societal issues. To what extent for example should the 'polluter-pays-principle' or a prohibition of certain substances be applied instead of elaborate processes of elimination at the end of the chain? If such solutions are not feasible, then the coverage of construction or amendment costs of technical facilities can also be considered.

So far, ecological investigations have primarily focused on describing conditions and their assessment in relation to natural conditions. Establishing the scientific foundations for a substantiated ecological, hydrological and biogeochemical understanding of processes not only requires a sophisticated infrastructure but also joint activities.

The scientists at the Center for Advanced Water Research cover all the necessary requirements to address the described challenges with a unique combination of competences and research infrastructures:

1) Observatories with defined boundary conditions for long-term detailed studies (jointly-operated observatories within TERENO),
2) Infrastructure for the experimental analysis of causal relationships under laboratory and field conditions (mobile mesocosms, S2-laboratories and drainage channel facilities, well-equipped field sites),
3) Expertise on relevant stressors in hydrology, river ecology, urban water management, water chemistry, ecotoxicology and antibiotic-resistant pathogens) and
4) Competences in integrated modeling of the underlying ecological, biogeochemical and hydrological processes.

The thematic field of the Center for Advanced Water Research described here focuses on key processes and matter fluxes in the entire catchment (urban spaces, agricultural land, groundwater, reservoirs etc.), necessary to secure and sustain the quality and volume of water available to consumers and to facilitate the sustainable development of ecosystem processes and functions in all domains of the water cycle.

Based on this know-how and taking into account the social and societal conditions, specific management measures can be developed and implemented to optimise processes. New, effect-based monitoring strategies are being developed that can be implemented under changing boundary conditions (man, climate and ecology). These will be developed further into an integrated early-warning system that has the potential to be implemented not only in Central Europe but all over the world.

THEMATIC FIELD 2
WATER SCARCITY IN THE REGIONAL CONTEXT

Sustainable resource management in particular in water scarce catchments

Nowadays, the assessment and management of water resources are mostly conducted on the river catchment level. These hydrologically defined natural units provide a framework for integrated concepts such as the European Water Framework Directive (EU WFD). Reinforcing this concept, the Integrated Water Resources Management (IWRM) has developed as a process for the coordinated development and management of water, land and natural resources. It pursues the goal of achieving economic and social wellbeing together with a sustainable use and conservation of aquatic and terrestrial ecosystems. The central role of institutional framework conditions in IWRM is evident – they form the basic starting point for a regional and international water policy. In this respect, the European Water Framework Directive is an internationally renowned example. With conditions of water scarcity in arid regions of the world, the conservation and management of soils and groundwater using resilient technologies are increasingly becoming a focal point of interest. The work of the Center for Advanced Water Research aims to come up with tailor-made, flexible management strategies as well as suitable institutional frameworks – particularly in water-scarce regions such as the Mediterranean region or vast expanses of Sub-Saharan Africa. This involves simultaneously considering various resources in the nexus water-soil-food-health. Here, the differentiation between „green" and „blue" water is a useful approach. The share of „green" water found in plants is increased dramatically due to food production from agriculture (particularly due to irrigation - see Fig. 10). This kind of redistribution comes at the expense of „blue" water, which then becomes scarcer for other uses or for aquatic ecosystems. As a result, intelligent management and optimisation approaches become indispensable.

Fig. 10: Agricultural irrigation particularly in semi-arid regions consumes a substantial amount of available water resources. Irrigation technologies (left: water-saving drip irrigation, right: mobile sprinkler irrigation) have very different effects on the availability of freshwater resources. Overuse and mismanagement can lead to a salinization of soils and groundwater.

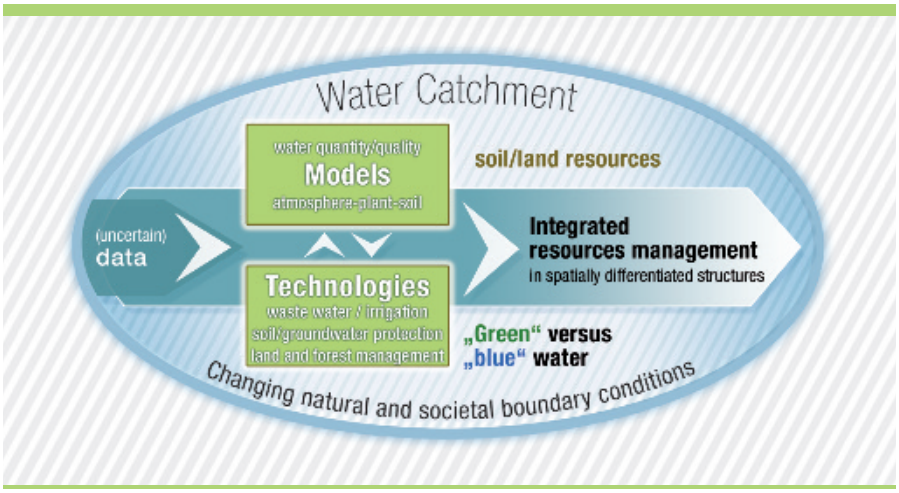

Fig.11: Structure of thematic field 2

Due to rapidly encroaching urbanisation all over the world, especially in regions characterized by water scarcity, clean drinking water and suitable water distribution systems with appropriate sanitation concepts are key dimensions of water security. In the rapidly expanding urban regions of the South, sustainable water resources management is increasingly determining societal development.

Thematic field 2 therefore prioritises the following:

1) The development of reliable models to assess the spatial and temporal variability of water and soil resources considering both volumes and chemical compositions, particularly in arid regions (interface with thematic fields 1 and 4). One particular focus of this work is the characterisation of resources under conditions of data shortage and considerable system uncertainties by implementing combined methods.

2) The development of sustainable technologies, among others for the treatment of waste water, enabling an efficient use of wastewater resources (e.g. sewage sludge) while at the same time conserving water and soil resources (interface with thematic field 3). This field also includes research on resource-efficient wastewater purification and recycling as well as efficient irrigation technologies, development of methods for the artificial recharge of groundwater, methods to prevent erosion and integrated land-use systems (e.g. agroforestry systems).

3) The analysis of economic and legal framework conditions and the effects of different management strategies on natural systems and society as well as the development of appropriate regulatory, legal and administrative management strategies (interface with thematic fields 5 and 6).

4) The development of spatially-explicit land use strategies to achieve common goals in water resources management, agriculture, forestry and soil conservation (interface with thematic fields 5 und 6).

With research expertise in the fields of hydro(geo)logy, soil sciences, wastewater management under arid conditions, (agro-)forestry, ecology, hydro-chemistry, meteorology/climatology, ecotoxicology, environmental technologies, economics, sociology and international water law, the interdisciplinary Center for Advanced Water Research is in a position to make a considerable contribution to a better understanding of the nexus water-soil-food-health. The resulting system understanding can be used to develop efficient and sustainable management/ implementation strategies.

A grand challenge in developing management strategies, particularly in regions with water scarcity, is the lacking or limited point and spatial monitoring data available for these regions. For this reason, it is difficult to apply conventional methods of model development and model validation as they will show high uncertainty.

Fig.12: Water level of a river in East Africa at low water

Building on years of experience from scientific projects in arid areas, such as the Middle East, Brazil, and China, as well as the monitoring infrastructure TERENO-MED and modeling expertise, while also benefiting from close cooperation with other thematic fields at the Center for Advanced Water Research, this thematic field offers outstanding expertise for developing novel and robust monitoring and modeling concepts by linking different information sources and data forms on different spatio-temporal scales. The same applies to methods for assessing management strategies and decision-making under uncertainty.

THEMATIC FIELD 3
URBAN WATER RESOURCES MANAGEMENT (UWRM)
Processes and dynamics of matter fluxes in the urban system

Urban regions put pressure on water resources, link matter, energy and water fluxes and pollute water bodies and the environment. The entire system is extremely complex due to the diversity of substances that get into the water cycle through different routes and with different dynamics, as well as through feedback effects. To map interactions of the urban technical system with used or contaminated resources, system borders need to be extended and the interaction of water in the city and its surroundings understood as urban water resources management (UWRM).

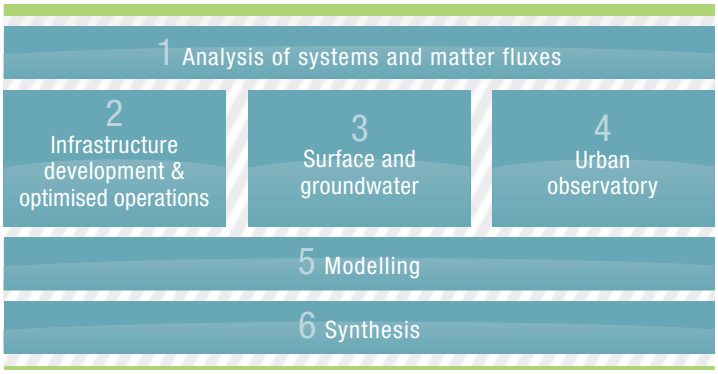

Fig.13: Structure of thematic field 3

All over the world urbanisation is a process that is encroaching rapidly, increasing regional pressure on the quantity and quality of available water resources. Among the pollutants occurring in urban spaces are micro-pollutants, nano-particles, pathogens, antibiotic-resistant microorganisms and endocrinal-active substances etc. that can be a potential threat to both ecosystems as well as water quality.

Water management in urban areas must rise to the demand for robust future concepts as well as the following challenges:

- Strategies for water utilisation, optimisation of water efficiency and the implementation of concepts to reuse wastewater, especially in the urban sector,
- The development of infrastructure in rapidly growing urban regions with centralised, semi-centralised or decentralised approaches,
- Strategies for system operations in urban and sub-urban regions with a declining population,
- Handling of new pollutants from urban sources,
- Resource recycling,
- Model-based representation of the total system for optimisation and decision support.

The upcoming problems in water management cannot be solved by an isolated water supply or from a wastewater discharge perspective. Instead, problem-solving approaches must consider all the mechanisms of the urban agglomeration and its environment. Furthermore, water resources management is to be integrated into comprehensive urban planning and development strategies, facilitating more coordinated and reliable urban planning including the (re)construction of new infrastructure.

The competences of this thematic field at the Center for Advanced Water Research cover the following fields:

1) **Analysis of systems and matter fluxes:** A fundamental description of the complex urban water resource system with interactions between technological and natural compartments. Relevant sources and paths in the urban water system are identified emanating from a matter flux system and providing a basis for holistic management.

2) **Development of infrastructure and optimisation of technological systems operations** and interfaces to the natural compartments. Robust criteria will be identified to develop strategies for the development or deconstruction of the urban water infrastructure as a prerequisite for the efficient use of resources (not only water). Methods for supporting decisions on the choice of supply and sanitation systems (centralised, semi-centralised, decentralised) as a function of basic conditions (size of the agglomeration, population density, water availability, water pollution, prevailing system) are to be equally developed as are processes for eliminating micro-pollutants, antibiotics and antibiotic-resistance, as well as promoting resource recycling.

3) **Linking groundwater and surface water to urban water management systems:** Groundwater is influenced in terms of volume and quality by extraction for the water supply, by leaky sewage systems and leaching. Surface waters become polluted from final effluent and discharge from sewers both short and long term. A falling groundwater level on the other hand reduces the low-water flow and consequently the self-purification capacity of river water. Researcher groups at the Center for Advanced Water Research are developing an intrinsic quality management of waterbodies, whereby instead of the self-purification capacity exclusively being oriented towards reducing external pressures for waterbody protection, ecosystem services are also taken into account.

4) **Urban observatories:** „Urban observatories" that are continuously in operation will be set up and operated within the Center for Advanced Water Research. The transport- and turnover processes of ecologically-relevant substances in wastewater and rainwater are analysed within the observatories reaching from the rainwater input, the drainage and sewage systems into watercourses and the groundwater. They will be used to advance and calibrate models, in particular at the interfaces between technological components and resources.The management of operations and data, as well as uncertainty analysis are based upon TERENO activities. Finally, monitoring strategies will be developed for all compartments in the urban system (i.e. for the technological system, urban groundwater, surface waters).

5) **Modeling:** Dynamic models from the fields of urban water management systems, groundwater and surface water with increasing spatial and temporal resolutions will be further developed and improved by research groups at the Center for Advanced Water Research. The long-term quality and quantity of the urban groundwater body is characterized by coupling it to flow and transport simulations of pipeline networks, watercourses and the unsaturated zone. River models are being improved and made more manageable by a better integration of the flow course influenced by urban depositions. Moreover,

geo-information and measured data are being adequately collated into a suitable form so it can be directly used for numerical modeling and simulation results then entered into a GIS.

6) **Synthesis:** Concepts for the technological and natural systems will be brought together by using evaluation concepts such as sustainability, resilience, adaptability or water footprint. By setting up an ontology, a formalized knowledge base, researchers at the Center for Advanced Water Research are working on a management tool and integrating the urban system in large-scale water resources management (interface with thematic field 2). Within strategic alliances among the partners, these concepts will be tried and tested in the observatories, put into operation, and realised as demo-projects.

Fig. 14: The interactions between the natural and technological compartments are of prominent importance in Urban Water Resources Management.

Fig. 15: Harmful pathogens can get into the environment through the sewage system. Scientists test sewage water to determine the origin and distribution of the microbes.

The aspects of this thematic field are addressed in the structure shown in figure 13. There are close cross-links with the thematic field 6 „Water Governance“ with an investigation of the socio-economic variables and institutional framework conditions on the development of the urban water system, whereby an integrative approach relates urban water systems, urban development, town planning und transport development.

THEMATIC FIELD 4
METHODS OF DATA COLLECTION AND INFORMATION PROCESSING
Monitoring, modeling of processes and data

New methods and technologies for observing Earth, such as satellites and hyperspectral remote-sensing or geo-sensor networks, provide data in a completely new quantity and quality for analysing terrestrial environmental systems. To optimally use the large array and diversity of this recorded data, appropriate data and modelling platforms must be developed with the assistance of high-performance computers and scientific visualisation technologies.

At the same time, models and model results must be validated and improved using data from ground truthing. For this, new concepts, strategies and technologies must be developed for measurements and long-term observations of environmental parameters.

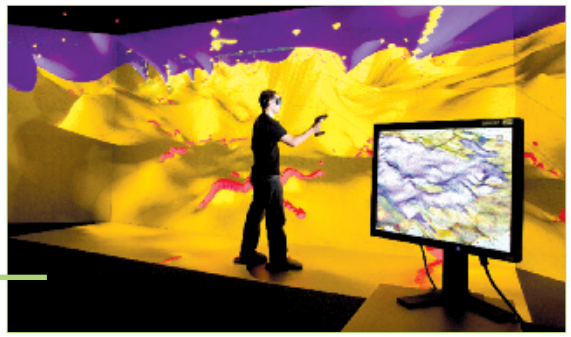

Fig. 16: In the visualisation center the real world can be reconstructed virtually: processes and correlations can be better understood.

This thematic field at the Center for Advanced Water Research encompasses extensive know-how on intelligent combinations of monitoring procedures as well as process and data modeling that follow the continuous workflow concept (see Fig. 17).

The competences in this field also comprise model coupling as well as the development, testing and adaptation of model systems. As a cross-sectional field, the thematic field „monitoring, process and data modelling“ extends into all research areas at the Center for Advanced Water Research.

Fig. 17: Workflow concept for intelligent monitoring, data and process modeling

For an optimal and efficient use of data, recorded by existing and new monitoring and exploration methods, various data processing and model components have to be coupled with one another. This can be ensured by incorporating individual processes and tools into a workflow that includes data recording, data management, data research and exploration, process modeling and finally analysis and synthesis. In this way, problems and bottlenecks in the data flow can be avoided.

THEMATIC FIELD 5
SOCIETAL AND CLIMATE CHANGE
Regional transformation strategies and scenarios

The opportunities and threats of using scarce water resources sustainably are becoming increasingly shaped by dynamic global driver processes like for example population growth, climate change, land-use change, economic development, globalisation and urbanisation. However, such developments not only have very different effects and variable time paths on the respective regional level that is relevant for decision-making about water resources (e.g. climate fluctuations, trends and vulnerability), but they also interfere with each other and at the same time with specific regional processes (i.e. demographic changes, regional economic structures, legal frameworks, changes in approaches etc.) including management and adaptation measures.

Dynamic boundary conditions result in a high degree of uncertainty regarding the course of development as well as the future effectiveness and efficiency of measures in Integrated Water Resources Management. Knowledge about potential future scenarios and their extent as well as an accurate understanding of spatiotemporal interactions concerning the availability of water resources are key to an integrated water resources management. The central challenge here is to develop regionally-adapted transformation strategies for utilisation systems with three principal dimensions:

- The presentation and assurance of a regionally-specific sustainability path (transition to sustainability),
- Adaptation to natural and socio-economic framework conditions that change over time (adaptation to changing frameworks),
- Alteration and orientation of societal needs and demands to water resources that change over time (sustainable and goal-oriented management).

Fig.18: Floods threaten settlements and infrastructure; as recently seen along the Elbe in June 2013.

Against this background, the Center for Advanced Water Research pursues the following goals in this field:

1) The appropriation of spatio-temporal knowledge on global and regional change processes on scales relevant for decision-making, the observation and analysis of the dynamics of regional change processes including a spatio-temporal identification of patterns for urban and regional water systems,
2) The development of an integrated method by the environmental and social sciences to identify, describe and predict regionally-specific availability, claims, risks and vulnerability, among others through scenarios,
3) Methods for analysing and designing the regionally-adapted transformation of water resources and water management systems (change management).

Fig.19: In some regions around the world fish farming is an important source of income.

This thematic field has numerous interfaces with other thematic fields at the Center for Advanced Water Research. On the one hand, results from the thematic field „Methods of data collection and information processing“ must be used for observations and to validate simulations of development dynamics and on the other hand scenarios as well as transformation and adaptation strategies must be developed for the thematic fields „Urban water resources management“, „Water scarcity in the regional context“ and „Quality and dynamics of the water cycle“, that depend on highly resolved spatio-temporal information and the respective tailored transformation concepts. Conversely, results from this thematic field flow into „Water governance“, to ensure goal-oriented testing and implementation.

The TUD and the UFZ provide extensive expertise in this thematic field, including climate observation, analysis and modeling, changes in the natural water balance (changes in availability), the retrospective analysis and projection of land use changes, the investigation and simulation of interdependencies between climate and land use (e.g. regional greenhouse gas sinks), and the simulation of inner-annual change processes using growth models. Furthermore, the existing expertise includes the projection of demographic and economic change, the analysis of driving forces in changing water utilization systems on the one hand, and management oriented aspects such as regional adaptation (e.g. adaptation to climate change, vulnerability analysis, risk management, legal frameworks), specific spatio-temporal transformation pathways of e.g. water infrastructures, interdisciplinary concepts for addressing regional scarcity on the other, as well as participatory processes for strategic planning using scenario approaches.

THEMATIC FIELD 6
WATER GOVERNANCE

Management targets, obstacles, strategies and instruments

The thematic field of „Water Governance“ is concerned with issues encompassing societal institutions and regulatory mechanisms for Integrated Water Resources Management (IWRM). The starting point of the research is the insight that correlations between the water balance and society are greatly influenced by regulatory and control systems. As a result, sustainable solutions for various contemporary „water issues“ can only be found through the analysis and furtherance of governance structures and management processes. The aspects to be taken into consideration range from the political, legal and financial contexts through network structures between stakeholders to the development and implementation of strategies across organisations with the respective decision-making and management processes. Promoting sustainable solutions also requires an assessment of the effectiveness of formal and informal regulatory instruments while also including social, economic and ecological aspects.

The thematic field of „Water Governance“ considers various issues in an integrative approach, from water conservation and the utilisation of water resources to the prevention of risks from extreme events such as flooding and droughts, while also investigating success factors and constraints for an effective and sustainable management from a political, administrative and scientific perspective.

Building on long-term research experience in the field of „Water Governance" and the well-established cooperation between the UFZ and the TU Dresden, the Center for Advanced Water Research pools competences from various disciplines. In particular, this includes the legal, political, economic and planning sciences. In terms of research, the following topics are priority:

1) **Setting targets and priorities – from the concept of sustainability to the development of concrete goals for IWRM:** The requirements of an integrated water management include the necessity to set long-term and concerted goals that serve as a framework for the utilisation of water and waterbodies, leading to the selection of management measures for achieving sustainable solutions and enabling the monitoring of performance. Existing objectives are to be adopted and examined carefully as to how they can be fitted into an integrative system with sustainable targets and priorities. On the global scale, this mainly concerns targets from the UN Convention on Water, notably the „human right to water“, the call for „a fair distribution of trans-boundary water resources“ and the important commandment not to impair these water resources detrimentally. Furthermore, there is also the UN's Hyogo Framework for Action 2005-2015 target of reducing risks from extreme events and climate change. These basic targets require a progressive scientific consideration and interdisciplinary clarification in the respective sectors such as agriculture, industry, transport and town planning. The Center for Advanced Water Research will be involved in the discourse on these central targets both on the international as well as on the regional level (for selected research regions). The EU's water regulation acts as an important reference for issues of target and priority

Fig. 20: Cooperation between scientists and decision-makers is a prerequisite for successfully implementing research results in policy-making and in practice.

setting. Among others the goal of achieving a „good status“ (and exceptions to this) will be tested and further developed.

2) **Integrated planning measures and instruments:** The development of integrated concepts for measures and more efficient instruments for an IWRM gained considerable momentum with the first management cycle of the EU Water Framework Directive. An evaluation of the first round of management plans and program measures shows large differences in standards, approaches, quality and concreteness. There is an obvious need for continuative ecological and economic assessments and recommendations that also consider synergies and conflicts with flood risk management. For this reason this has been made another central thematic field for research and consultation at the Center for Advanced Water Research. A unique pooling of expertise from the natural and social sciences provides excellent conditions for establishing measures and combinations of measures from an overall assessment and for providing decision makers with a more detailed picture of international regulation, its effectiveness as well as adverse and reciprocal effects from global regulations all the way down to micro-economic levels. This also enables a re-examination of assessment logic regarding mismanagement potential and the implications from the uncertainty of future developments.

3) **Governance structures and management processes:** The complex challenges of an IWRM cannot be met without the appropriate institutional framework conditions and administration capacity. In this respect it is imperative to set up decision-making and executive network structures for enforcement that work in an interdisciplinary way. In the multi-level political-administrative system there is also the challenge of appropriately distributing competences so that fruitful cooperation can be guaranteed centrally, while at the same time allowing enough room for decentralised solutions adapted to specific situations. Here it is also important to involve enterprises as indispensable stakeholders. At all levels, governance structures need to be developed realistically, so that they can work to their full potential in each individual case. In this respect the thematic field ‘Water Governance’ that continues previous lines of research, strives to develop both abstract and general as well as concrete organisation prerequisites from case to case and options for an effective IWRM. Furthermore, and not lastly, this thematic field deals with management processes as well as the development and implementation of strategies. One focus here is the interaction between anticipation and resilience.

Fig. 21: Training of young scientists forms the basis of future CAWR-research.

4.2 EDUCATION & TRAINING

The second pillar of the Center for Advanced Water Research is education and training. Research-oriented training is indispensable for developing novel and innovative strategies and methods in relation to the grand challenges in the water sector as well as for sensitizing future decision-makers to system approaches. The center builds on and aims to advance the following existing programs :

- **Masters programs:** the TUD offers a wide spectrum of Masters courses Hydro-Science and Engineering, Water Management, Hydrology, Hydrobiology, Waste Treatment and Contaminated Site Management, Geodesy, Geography, GIS technologies, Spatial Development and Natural Resources Management, and Forest Sciences. The courses and lectures are held by the professors of the TUD as well as several department heads from the UFZ and are to be developed through close cooperation in the future.
- **Graduate school HIGRADE (Helmholtz Interdisciplinary Graduate School of Environmental Research):** The interdisciplinary PhD school in the field of environmental research is hosted by the UFZ and is run by the UFZ and its partner universities. With its wide range of topics, HIGRADE encourages interdisciplinary thinking and research among students, provides them with excellent research facilities and supports them in publishing their research and implementing their inter- und transdisciplinary know-how.
- **Centre for International Postgraduate Studies of Environmental Management (CIPSEM):** Since 1977 CIPSEM has been responsible for holding post-graduate courses at the TUD for experts from developing and emerging countries in cooperation with UNEP (United Nations Environmental Program), UNESCO (UN Educational, Scientific and Cultural Organization), the Federal Environment Ministry (BMU) and the Federal Environment Agency (UBA).
- **UNU-FLORES:** The Institute of the University of the United Nations for the „Integrated Management of Material Fluxes and Resources“ was initiated by the two principles from the TUD and the UNU, the Federal Ministry of Education and Research (BMBF) as well as the Saxon State Ministry for Science and Arts (SMWK) and officially established in December 2012 in Dresden. Since its establishment there has been close cooperation between the TUD, UFZ and UNU, and hence there is a close connection of the Center for Advanced Water Research with the activities of UNU. In particular with a view to developing and emerging countries (regional focus: Sub-Saharan Africa) there is enormous potential from this cooperation to make use of the competences of the Center for Advanced Water Research in these countries.

- **Capacity Development within the framework of the International Water Research Alliance Saxony (IWAS):** In the joint research project IWAS an interdisciplinary concept has been developed since 2009 providing a framework for capacity development from the individual, through the institutional level to the regulatory system. This concept provides an outstanding basis for sustainable capacity development, which is to be integrated into the activities of the Center for Advanced Water Research.
- **IWRM E-learning (together with IHP):** as a part of the (open access) education and capacity development, alongside classical training, online instruments and E-learning methods will be adopted by the Center for Advanced Water Research. An E-Learning module on Integrated Water Resources Management was already designed within the framework of IWAS in cooperation with the International Hydrological Program from UNESCO (IHP) and serves as a pilot project.

Other various training programs are regularly hosted by the UFZ and the TUD and will be offered in the future as jointly run programs by the Center for Advanced Water Research (national/international summer schools, courses with UNEP/UNESCO/BMU, DAAD scholarships and courses, etc.).

Fig. 22: The transfer of research results involves numerous exchange processes and interactions between science and praxis.

4.3 TRANSFER

The thematic focus of the center on research and training provides a range of application fields, both in Germany as well as internationally. TUD and the UFZ have excellent contacts that enable both a transfer and application of research work: cooperation and contacts with the GIZ (German society for international cooperation) and the KfW (German Development Bank) and hence also with the TZ-EZ (technological and development work through the BMZ), with international training institutes (e.g UNU-FLORES, CIPSEM-UNEP, IHP), with stakeholder groups such as the German Water Partnership (GWP), but also direct contacts with federal, national and international ministries.

Against a background of transition processes in Germany and Europe since 1990, both institutions (UFZ and TUD) have long-term experience in developing strategies and instruments to master transition processes in the environment and society (key word „Global Change“), which at the project level (e.g. IWAS – International Water Research Alliance Saxony) have already been successfully adapted and implemented in some transition countries. Moreover, scientists from both institutions provide consultation to decision-makers on policies and administration in designing sustainable regulatory frameworks as well as the implementation of regulatory approaches.

A COOPERATION BETWEEN SCIENCE AND INTERNATIONAL COLLABORATION HAS TREMENDOUS POTENTIAL IN THE WATER SECTOR

By Tanja Gönner, board spokesperson from the "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ) GmbH

Tanja Gönner

Water is more than the basis of life. It ensures our food and energy production and acts as a means of transportation as well as being an indispensable economic and cultural good.

It is one of the greatest challenges of our time to sustainably manage limited water resources – in spite of continuous population growth, in spite of urbanisation and globalisation and in spite of increasingly frequent flooding and drought events. The "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ) GmbH pursues an integrated water resources management approach, to ensure the basic human right to drinking water as well as hygienic wastewater systems and an increased economic and social benefit of water, without jeopardising its ecological sustainability.

The current debate on defining the post-MDG's, that is the goals that should follow on from the Millennium Development Goals of the United Nations, makes it clear that on the one hand we have made considerable progress i.e. in terms of water supply, the set course however is still not satisfactory: the fact remains that 2.5 billion people in the world are still living without toilets or hygienic wastewater systems and by 2050 it is very probable that 2.3 billion people will be living in regions with acute water scarcity.

The management of water resources adapted to climate change and a sustainable supply of water and sanitation services for the population does not only call for a „nexus" between water, energy and food security, but also relies on the effective cooperation of stakeholders (politicians, economists, citizens and not lastly scientists). An interdisciplinary scientific cooperation in the water sector, as initiated by the Helmholtz Center for Environmental Research and the Dresden University of Technology, makes a considerable contribution to this and offers new opportunities for cooperation for the GIZ and for international cooperation on the whole. Cooperation between science and international collaboration has tremendous potential for conducting scientific research on the fundaments, context and prerequisites for sustainable development in the water sector and for making these comprehensive in all their complexity, to derive options for action that can be applied in practice and incorporated into development measures.

THE RIGHT TIME TO ESTABLISH THE „CENTER FOR ADVANCED WATER RESEARCH“!

by Gunda Röstel, deputy chairperson of the board for the German Water Partnership e. V. and University council chairperson of the TU Dresden

Gunda Röstel

Water is the source of life. For this very reason the supply of clean drinking water, but also the disposal and treatment of wastewater and on the whole an integrated water resources management are among the most pressing issues to be tackled through cooperation in economic and development politics. Only in those areas where this can be guaranteed, will society, and the economy prosper and wealth will follow.

With more than 7 billion people now sharing an Earth with limited and unevenly distributed drinking water reserves, only collective and concerted efforts will be successful in this matter. Not lastly, the unpredictability of climate change exacerbates this challenge. It is precisely this approach that the UN adopted in its Millennium declaration where it defined the water issue as one of the top issues to be tackled.

The German water sector has a lot to offer for global water management – more than 100 years of precious know-how in water supply and wastewater management as well as research and training at the highest level. The German Water Partnership (GWP) is a network and contact for German, internationally-committed enterprises and universities/ scientific institutions working in the field of water. With more than 350 members, GWP has been helping since 2008 to make German water expertise internationally accessible. At this point, the strong network of enterprises, scientific institutions and organisations from all fields of the water sector is linked to the pillar „research transfer“ from the „Center for Advanced Water Research“. With the close collaboration between scientists, economists, public society and policy-makers, the GWP supports the interpretation and implementation of scientific findings into practical measures. Founding the „Center for Advanced Water Research“ has therefore come at the perfect time as it will fulfil an essential pivotal role.

From this unique institutionalised collaboration of two scientific heavyweights in the field of water research, GWP anticipates that German scientific know-how on water will be realised and accepted more readily internationally. We look forward to a fruitful cooperation!

THE CENTER FOR ADVANCED WATER RESEARCH PROVIDES A STRONG PLATFORM FOR INTERNATIONAL COOPERATION

By Prof. Dr. Reza Ardakanian, Founding Director of UNU-FLORES

Reza Ardakanian

On behalf of the United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) I would like to congratulate Prof. Dr. Müller-Steinhagen and Prof. Dr. Teutsch as well as all involved scientists at TU Dresden and UFZ on the establishment of the Center for Advanced Water Research (CAWR). From UNU perspective, considering the global challenges for sustainable water management and the need for new technologies and interdisciplinary and truly integrative approaches in research and management, joining forces is surely required.

Especially with respect to the envisaged sustainable development goals and the post-2015 development agenda the establishment of the CAWR is a timely initiative to address global challenges in the water sector such as population growth, climate change, land-use changes, urbanization etc. The institutionalizing of a strategic cooperation between TUD and UFZ realized in the CAWR seems highly reasonable, feasible and appropriate given the long-standing and close cooperation of both institutions in the water sector. It will help to add water science as another area of excellence within the Excellency Initiative in which TUD has been successful.

UNU-FLORES was established in Dresden in 2012 and is committed to advance a nexus approach to the sustainable management of environmental resources, focusing in particular on water, soil and waste. We have developed close relations with TUD, in particular with the Faculty of Environmental Sciences based on a Framework Agreement signed in December 2012. We have also identified many areas of mutual interest with UFZ and will be happy to continue and even intensify the cooperation within the framework of the CAWR, whose main focus (integrated water resources management under global change) is very close to UNU-FLORES´ mandate and core areas of activities. Acting as a think-tank for the UN system and Member States, building on a dense (and still expanding) network of international partners (UN agencies, universities and research institutions, governmental partners in many countries worldwide, NGOs etc.), UNU-FLORES will be able to add value and help in the internationalization of the activities of the CAWR.

UNU-FLORES will be a partner in education and capacity development. In addition, however, it aims at establishing close cooperation in policy-relevant research in all thematic fields of the CAWR.

The Center for Advanced Water Research could become a platform to cluster and bundle not only the competencies and capacities of TUD and UFZ in the water sector, but also to facilitate and coordinate additional partnerships. These should, despite the CAWR becoming a large player even at the international level, still be essential for successful and policy-relevant research and its implementation. UNU-FLORES is ready to take its role in this regard and is looking forward to a close and fruitful cooperation.

5. Organisation & Management

The Center for Advanced Water Research has a **coordination office** led by a head that is responsible for its operations, its administrative coordination as well as public relations of the center, the coordination of its research results and its outreach products. The head of the coordination office is also responsible for external partnerships (national/ international). He/She will report to the assembly of the partners (TUD and UFZ) as well as to the funding bodies (BMBF, Helmholtz, and federal states). The head of the coordination office will be supported by a secretariat. The coordination office will be jointly funded by the TUD and the UFZ.

The **steering group** is responsible for setting strategic targets and thematic steering at the Center for Advanced Water Research. It will make decisions about overall investments, and the thematic focus of new appointments. The steering group comprises of the head of the coordination office, a speaker for each of the five thematic fields, speakers for the fields of training and transfer as well as a management representative from both the UFZ and the TUD.

Research is organised around so-called **thematic fields**, each of which has a nominated speaker. Research and training are also organised based on the thematic fields.

The Center for Advanced Water Research is supported by an **International Advisory Committee** that supports the Center for Advanced Water Research in its strategic orientation as well as in its focus on science, transfer and training.

The assembly of the partners is formed by the scientific executive board of the UFZ and the rectorate of the TUD. The funding organisations of the research are involved in the work of the Center for Advanced Water Research through the board of trustees from the TUD and the supervisory board from the UFZ. Regulations on the governance and finance structures are detailed in the cooperation contract between the UFZ and the TUD. The Center for Advanced Water Research generally has an open structure, allowing TUD and UFZ employees to become involved in CAWR at any time. Furthermore, the involvement of other external partners is also explicitly welcomed.

The organizational structure of the Center for Advanced Water Research is shown in Fig. 23.

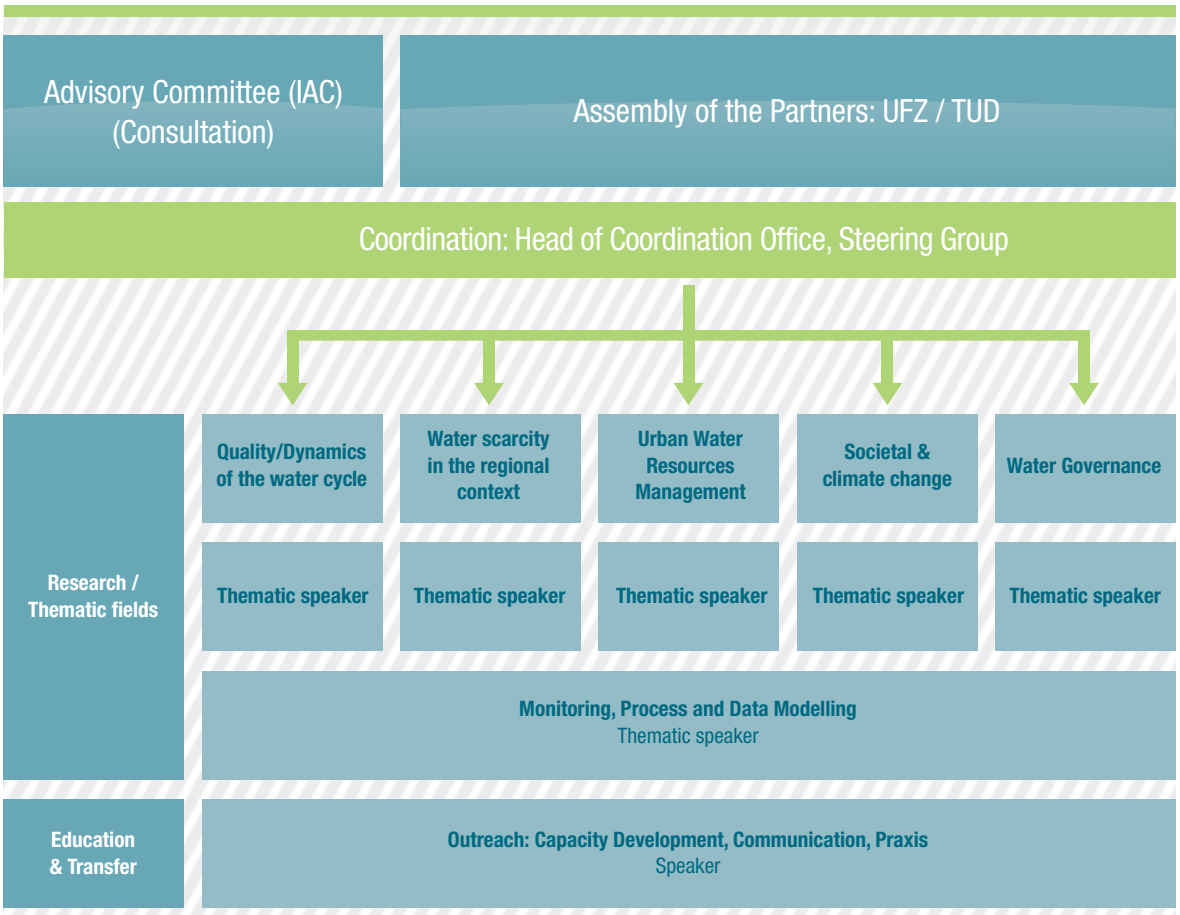

Fig. 23: Organisational structure of the Center for Advanced Water Research

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