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**INTERNATIONAL HYDROLOGICAL PROGRAMME (IHP)**

**EIGHTH PHASE**

***“WATER SECURITY: RESPONSES TO LOCAL, REGIONAL, AND GLOBAL CHALLENGES”***

**STRATEGIC PLAN**

**IH-VIII 2014-2021**



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## CHAPTER 1: INTRODUCTION

UNESCO’s International Hydrological Programme (IHP), founded in 1975 and implemented in six-year programmatic time intervals or phases, is entering its eighth phase to be implemented during the period 2014 – 2021. IHP has evolved from an internationally coordinated hydrological research programme into an encompassing, holistic programme to facilitate education and capacity building and enhance water resources management and governance. IHP facilitates an interdisciplinary and integrated approach to watershed and aquifer management, which incorporates the social dimension of water resources and promotes and develops international research in hydrological and fresh water sciences.

The new phase of IHP follows the Millennium Development Goals (MDGs) era and envisions new challenges to be set in Rio+20. During its eighth phase, IHP aims to improve water security in response to local, regional, and global challenges. For our purpose, water security is defined as **the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards -- floods, landslides, land subsidence,) and droughts.** Given population growth, degradation of water quality, growing impact of floods and droughts and other hydrological effects of global change, water security is an increasing concern. Consequently, the overarching focus of the IHP eighth phase is encompassed in its title **“Water security: Responses to local, regional, and global challenges”**. To deal with the complex, rapid environmental and demographical changes (e.g. population growth and vulnerability to hydrological disasters, global and climate changes, uncontrolled urban expansion, and land use changes) holistic, multidisciplinary and environmentally sound approaches to water resources management and protection policy will be sought. The eighth phase of IHP reflects a

deeper understanding of the interfaces and interconnections between the water – energy – food nexus, which aims to further improve integrated water resources management (IWRM). The role of human behavior, cultural beliefs, and attitudes toward water, and the need for research in social and economic sciences to understand and develop tools to adapt to human impacts of changing water availability, are challenges to be addressed in the eighth phase of IHP.

In response to the priorities and needs of Member States, IHP-VIII focuses on six knowledge areas translated into themes. These themes address issues pertaining to managing water security, water quality and pollution control; adaptation to the impacts of climate change and natural disasters on water resources; management and protection of groundwater resources for sustainable living and poverty alleviation in developing countries and in arid and semi-arid regions and small islands; integration of catchment scale ecohydrological concepts and processes in advanced water management models; management of water resources for human settlements of the future; and water education as a key element to attain water security. These six themes are further developed in chapter 5. IHP-VIII has been designed to allow for a high degree of connectivity between topical areas. To connect thematic contents, crosscutting issues are addressed across the defined areas of knowledge or themes and are focused on: conjunctive surface water-groundwater sustainable management in an IWRM based on holistic and environmentally sound approaches as well as social and cultural traditions; integrated management consistent with transboundary water resources to prevent and/or overcome potential international conflicts over water; evaluation of the impact of key global change drivers on water resources availability and quality and population vulnerability; formulation of the framework for water governance policy based on multilevel and trans-sectoral approaches and integration of water stakeholders and general public; endorsement of the effort in water education, training, capacity building and hydrological research. In particular, IHP-VIII endorses the UNESCO goals to further equal opportunities for women and children.

However innovative the Eighth Phase is in itself, various activities emerge from previous IHP Phases and IHP Programmes (ISARM, PC-CP, IFI, HELP, ISI, FRIEND, G-WADI, GRAPHIC, JIIHP, UWMP and WHYMAP and the newly established IDI). In this context, a principle for IHP-VIII has been assuring continuity of needed IHP programmes and projects, while also responding to new challenges identified by Member States. IHP-VIII brings innovative methods, tools, models, technologies and approaches into play to optimize resources and capitalize on the advances of water sciences as well as social and/or economic opportunities while consolidating, expanding, and strengthening its implementation mechanisms.

## **CHAPTER 2: PRESENT STAGE AND MAJOR DRIVERS IN THE POST-MDG DECADE**

### **THE GLOBAL WATER SITUATION**

Water resource challenges to attain water security are increasingly taking on a global dimension among governments due to increasing water scarcity and uncertainty with the associated effects on water for people, energy, food and ecosystems. When inadequate in quantity and quality, water can serve as a limiting factor in poverty alleviation and economic recovery, resulting in poor health and low productivity, food insecurity, and constrained economic development. Even though the total amount of global water is sufficient to cover average global and annual water needs, regional and temporal variations in the availability of water is causing serious challenges with over two billion people living in severely water-stressed areas (Oki, T. and Kanae, S., 2006, *Global Hydrological Cycles and World Water Resources*, *Science* 313: 1068-1072). Alongside the natural factors affecting water resources, human activities have become the primary 'drivers' of the pressures on our planet's water resources systems. Human development and economic growth tripled the world's

population in the 20<sup>th</sup> century, thereby increasing pressures on local and regional water supplies and undermining the adequacy of water and sanitation developments. These pressures are in turn affected by a range of factors such as technological growth, institutional and financial conditions and global change (UNWWDR 3 2009). In the next 50 years, the world's population is expected to further increase by approximately 30% with most of the population expansion concentrated in urban areas. More than 60% of the world's population growth between 2008 and 2100 will be in sub-Saharan Africa (32%) and South Asia (30%). Together, these regions are expected to account for half of world population in 2100 (UNDPR 2010). These pressures call for more innovative ways of managing water resources, especially where the consideration of socio-economic systems have key importance for the development of adaptive and sustainable water management strategies to reduce human and ecological vulnerability (Folke C, Hahn, R, Olsson, P., Norberg, J. (2005). Along with increasing demands for water, population growth - coupled with industrialization and urbanization - have serious consequences on water quality and the environment. In addition to the complexity imposed by increasing population pressures and climate change scenarios, trade in goods and services that embody water in their production (*virtual water*) may potentially increase water stress in the exporting countries. Companies with holdings in water-stressed areas affect the local situation through their *water footprint*. Consumers in the emerging economies may intensify water stresses elsewhere through these processes. The global water crisis thus is not about having too little or too much water. It is a crisis of water governance so that billions of people – and the environment – suffer badly (World Water Council 2000, World Water Vision, Earthscan Publications Ltd, ISBN 1 85383 730 X, pp. 108).

## THE INTERNATIONAL ARENA

The uneven distribution over time and space of water resources and their modification through human use and mismanagement have led to water crises in many parts of the world. Deaths and material damage from extreme floods can be high, and more intense droughts, affecting increasing numbers of people, have been observed during the first decade of the 21st century (UNWWDR 3 2009). Recently, the water sector has taken to the international arena to consider and debate these problems and difficulties in large international conferences. Often called "mega-conferences," these massive gatherings have become popular sites for debating global environmental governance - a concept encompassing the people, processes, and institutions that guide the management of natural resources (Varady, R.G., K. Meehan, and E. McGovern. 2008. *Charting the emergence of 'Global Water Initiatives' in world water governance. Physics and Chemistry of the Earth*). The importance of water resources and ecosystem management for sustainable development has been highlighted and recognized in these international fora and conferences.

It is in this international context that the concept of sustainable development defined within the Agenda 21 led to the adoption of UN conventions (biodiversity, climate change and desertification) and to the adoption of the Millennium Development Goals (MDGs) which recognize the key role of water resources. In addition, the recognition of the importance of water for sustainable development has led to the establishment of international fora, events and programmes, including the World Water Forum series (WWF1,5), World Water Development Report series (WWDR1,3), World Water Day, and the Decade on Water for Life (2005-2015). Similarly, within the Decade for Education for Sustainable Development (2005-2014), numerous efforts are being undertaken to better incorporate water in the curricula, from kindergarten to tertiary education. Within the same dynamics, various international entities have been created for the promotion of sustainable management of water resources, such as the Global Water Partnership (GWP) and the World Water Council (WWC). But how can institutional sustainability be achieved while at the same time addressing the primary shortcomings of these major international initiatives - their frequent overlap and competition, the unchecked proliferation of new efforts, and the difficulty of measuring their effectiveness with some degree of precision? As importantly, is it possible to induce greater order and efficiency

democratically, avoiding imposed, and top-down solutions? Three key strategies *emerge*: Aim to transform overlap into a resource; address proliferation by strengthening networks rather than centralized authority; and tackle imprecision using multiple ways of measuring outcomes (Varady, R.G., K. Meehan, and E. McGovern. 2008. Charting the emergence of 'Global Water Initiatives' in world water governance. Physics and Chemistry of the Earth)

Water is clearly a cross-cutting issue and a catalyst for sustainable development. The Johannesburg World Development Summit (2002) was a major milestone and has clearly encouraged Member States to manage their national and regional water resources through integrated water resources management (IWRM) action plans. Even though water resources appear explicitly through the MDG7 with specific targets set to halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation, analysis from the UN Secretary General High Committee on Water and Sanitation has estimated that water resources count for one third for the achievement of the MDGs. In many regions, water resources management has received high level political commitments, such as in the adoption of the European Water Framework Directive, or the Africa Water Vision for 2025 adopted by heads of states. In Addition, an African Ministerial Council on Water (AMCOW) has been created to raise the profile of water resource within national development. Also, many Member States have undertaken significant efforts towards the preparation and adoption of policies on water or updating existing policies by integrating IWRM concept and practices.

In the international arena, within the United Nations system, the *One UN* approach is the main mechanism for the intervention of UN agencies at regional and country levels. UN activities now focus on key international commitments such as MDGs and Conventions within the framework of UNDAF (UN Development Assistance Framework), which are built on regional and national development priorities. It is expected that more emphasis will be given to sustainable management of water resources when implementing water supply, sanitation, and hygiene (WASH) initiatives under UNDAF. Within this context, UNESCO as the only UN specialized agency with a specific mandate to promote water science continues to play a pivotal role in assisting and guiding Member States in water related scientific, conservation, protection, managerial and policy issues. This is done through UNESCO's International Hydrological Programme, as UNESCO's water flagship programme. In addition, the UNESCO-IHE Institute for Water Education, established in 2003 to strengthen and mobilize the global educational and knowledge base for IWRM, contributes to meeting the needs for capacity building of the developing countries. To complement UNESCO-IHE's mission, 16 UNESCO water centres are working on thematic and area specific applied water sciences research to address country and regional priorities, and 25 UNESCO regional water chairs are providing a platform for information sharing and exchange. Similarly, the United Nations World Water Assessment Programme (WWAP) is another important UNESCO associated water related programme, which monitors and periodically reports on freshwater issues in order to provide recommendations, develop cases studies and enhance assessment capacity at a national level to inform the decision-making process. There is a strong synergy between the three UNESCO water related pillars, namely IHP, UNESCO water centres and chairs, and WWAP, to provide science, education, capacity building and data to support global and regional water management.

## **FROM THE MDGs TO GLOBAL CHANGES INFLUENCING THE WATER SECTOR AND WATER SCIENCES**

Despite the different efforts by countries and international programmes to promote achievement of the MDGs, many developing countries, particularly in sub-Saharan Africa and Asia, are not on track for the achievement of MDG targets (<http://www.mdgmonitor.org>), particularly those related to water supply and sanitation status (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012). During the VI World Water Forum that took place in Marseille in March 2012, it

was indicated that the MDGs for water supplies have been met. However, most of the progress achieved on access to improved drinking-water sources was made in China and India, but 780 million people in the world still do not have access to improved sources of drinking-water, and Sub-Saharan Africa accounts for over 1/3 of this. Furthermore, at the current rate of progress, the world will miss the MDG target on sanitation. Sub-Saharan Africa is significantly lagging behind in progress towards the MDG target with only 11 % increase in the number of people who gained access to an improved drinking-water source in 1990-2008. As an example, in rural areas of Africa, about 65 % of the population does not have access to an adequate supply of water, and 73 % are without access to adequate sanitation. In urban areas, 25 % and 43 % do not have access to adequate water and sanitation respectively. In fact, since the Water and Sanitation Decade, progress in coverage has stagnated, and more people in Africa are without adequate water and sanitation services today than in 1990. This is despite the significant funding provided for access to water for domestic and productive uses (agriculture, industry, and other economic activities) to reduce poverty and improve food security. Access to water, in particular in conditions of scarce resources, also has important gender-related implications, which affect the social and economic capital of women in terms of leadership, earnings and networking opportunities. In addition, equitable, reliable water resources management programmes reduce poor people's vulnerability to shocks, which in turn gives them more secure and fruitful livelihoods to draw upon in caring for their children. Access to water, and improved water and wastewater management in human settlements, also reduces transmission risks of mosquito-borne illnesses, such as malaria and dengue fever. Some 1.4 million children die each year from preventable diarrheal diseases. Ordinary diarrhea remains the major killer among water-, sanitation- and hygiene-related diseases, contributing to 43% of deaths. Sub-Saharan Africa and South Asia are the most affected regions (UNDP 2010).

Greater efforts at all levels (scientific/technical, institutional and policy) will be needed to achieve water-related MDG targets, particularly with the rapid population growth which will lead to more pressure on water and to competitions among the different uses at national and basin scales. Today 2.5 billion people do not use improved sanitation (of which 72 % live in Asia), and 780 million people in the world do still not have access to improved sources of drinking-water with sub-Saharan Africa accounting for over 1/3 of this. However, for developing countries in Africa, it appears that the inadequate access to basic water supply and sanitation services is not rooted in the inadequacy of available water resources but rather in financial and technological constraints and civil strife. Hence, lack of performance of economic development in Africa should be expected to pose a challenge to financing sustainable expansion of access to safe and adequate water and sanitation services for all, especially the poor, in the shortest possible time (Africa Water Vision 2025). The security of water at the heart of the global water crisis is rooted in power, poverty and inequality, rather than physical availability (UNWWDR 2006).

The significant role of people and their behaviors for sustainable water resource use and development has also been recognized. Indeed the main actors to reach sustainable water resources management are individuals and groups in households and communities with responsibilities for using water and water-related services (World Water Council 2000, World Water Vision, Earthscan Publications Ltd, ISBN 1 85383 730 X, pp. 108). Public authorities must empower and provide the data, services and technological support which households and communities cannot manage by themselves. Legitimate, transparent, participatory and social learning processes can effectively mobilize stakeholders, managers, and decision-makers for designing and implementing water resource policy as a strong deterrent to corruption. Corruption remains a poorly addressed governance issue in the water domain, and can lead to uncontrolled pollution of water resources, over pumping and depletion of groundwater, lack of planning, degradation of ecosystems, weakened flood protection, and urban expansion leading to heightened water tensions and other harmful effects (UNWWDR 5 2009). Scientists, water professionals and environmentalists must provide stakeholders with the information and tools they need to participate in decision



making. In addition, they should support institutional and community capacity building through water education and social learning strategies. Only by considering these different roles, abilities and actions of people and by working together, can sustainable water resources management be achieved.

Climate and land use changes are complicating current and future water management challenges by adding hydrological variability and uncertainty to the decision making process. Climate variability and change is a fundamental driver of change in water resources and an additional stressor through its effects on other external drivers (Claudio Cassardo and J. Anthony A. Jones, 2011, *Managing Water in a Changing World. Water 3: 618-628*) related to water demands from the agriculture, forestry, fishery and industry sectors. Limitations of traditional hydrological analyses and model approaches based on concepts of stationary hydrological events need to be understood and alternative methods explored to deal with environmental change (Wagener *et al.*, 2010)<sup>1</sup>. Water infrastructure, usage patterns and institutions have developed in the context of current conditions. Any substantial change in the frequency of floods and droughts, or in the quantity and quality or seasonal timing of water availability will require adjustments that may be costly in terms of financial, societal and ecological impacts, including the need to manage potential conflicts between different interest groups (IPCC, 2007). Impacts of increased precipitation variability on floods and droughts should be tempered by appropriate infrastructure developments and by adaptation in rural and urban water and land use management. Sustainable water resources management increasingly calls for strengthened scientifically based international cooperation to improve holistic understanding of surface- and groundwater hydrological processes and their response to changes in climate, land use and water demands. In addition, sustainable water resources management requires that new technologies and methodologies are developed and implemented for enhancing water productivity, financing opportunities, empowering people, improving the environment, coping with uncertainty, and adapting to climate change to achieve water security at various levels.

## **CHAPTER 3: CHALLENGES AND OPPORTUNITIES**

### **FACING GLOBAL CHANGE**

The world is changing. Societies are changing. The natural environment is changing. The planet is changing. The hydrological cycle is changing and the stationary of hydrological variables, once the fundamental assumption for hydrological, hydraulic and water engineering, requires validation under the different global scenarios. Designing global climate models realistically is a challenge due to the need of incorporating the many physical processes involved in the hydrological cycle (Hack, J. J., J. M. Caron, S. G. Yeager, K. W. Oleson, M. M. Holland, J. E. Truesdale, and P. J. Rasch, 2006: Simulation of the global hydrological cycle in the CCSM Community Atmosphere Model Version 3 (CAM3): Mean features. *J. Climate*, 19 (11), 2199-2221). Therefore, currently used hydrological and water management tools need to be adapted and validated. In this context, a new socio-ecosystem approach to IWRM should be used to face present and future water management challenges. A new paradigm shift should be considered. A new generation of water practitioners and managers is needed.

In facing global change, why is the Eighth Phase of IHP calling for a new paradigm shift and a new generation of water practitioners and managers? Because, currently, close to 0.8 billion people lack access to safe drinking water sources and over 2.5 billion people lack access to basic sanitation – most of which live in developing countries. Lack of integration has caused sanitation to lag behind.

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<sup>1</sup> Wagener, T., M. Sivapalan, P. A. Troch, B. L. McGlynn, C. J. Harman, H. V. Gupta, P. Kumar, P. S. C. Rao, N. B. Basu, and J. S. Wilson (2010), The future of hydrology: An evolving science for a changing world, *Water Resour. Res.*, 46, W05301, doi:10.1029/2009WR008906.

Almost 85% of global wastewater is discharged without treatment leading to serious impacts on public health and the natural ecosystem. The number of deaths attributed to poor sanitation and hygiene alone may be as high as 1.6 million a year.

Achieving sustainable and resilient water and sanitation solutions is a major challenge, particularly in urban and peri-urban areas. The current model of urban water management and the corresponding infrastructures date back to the 19th century with the main driver being protection of public health that did not take sustainability criteria into consideration. The dynamic and ever increasing global and regional pressures coupled with inherited un-sustainability water management, the generations of the future will face problems in managing scarcer and less reliable water resources to satisfy urban, rural and industrial water needs.

Although water systems face multiple challenges, there are also potential opportunities, particularly in developing countries, to improve the supply, distribution and use efficiency of water. These will enable identification of suitable sustainable water management approaches based on ground conditions and lessons learned from the experiences and paths followed by most of the developed countries. The major challenges and opportunities are briefly discussed below.

## **CHALLENGES**

The current water systems are faced with several challenges, which can be categorized as technical, institutional, political financial and information-related. These challenges are further compounded by global and regional change pressures and associated risks and uncertainties. Sustainable water management in the future needs to address these challenges effectively.

### ***Technical challenges***

For a scientific viewpoint, a great challenge for the hydrological community is to identify appropriate and timely adaptation measures in a continuously changing environment. To this end, the main scientific gaps are: incomplete understanding of hydrological processes and links with atmosphere/biosphere/human society; appropriate techniques for data integration and/or assimilation, scaling and heterogeneity issues; predictive capabilities of hydrological processes and interactions and feedbacks with socio-ecological systems; and uncertainty estimation and communication. Moreover, our capabilities to make prediction in ungauged basins (PUB) should be further enhanced.

Centralized water and wastewater systems are the technologies of choice in most cities around the world. In many cases, the conventional systems are expensive, rigid and less flexible and have high energy demand and limited options for reuse of resources. In most developing countries water supply systems are characterized by intermittent supply, poor water quality and inadequate operation and maintenance. The systems have high leakage rates associated with the loss of water and are prone to cross contamination of the drinking water by foul water bodies. In addition poor drainage systems, lack of wastewater treatment and inappropriate solid waste management are major technical challenges.

### ***Institutional challenges***

Water utilities of developed countries are mostly well managed. However, they often operate as separate institutions for each of the subsystems (silo perspective) and lack integration among the wide range of institutions. In most of the developing countries there is lack of appropriate institutions at all levels or the chronic dysfunction of existing institutional arrangements. Many of the utilities are state owned and follow inefficient practices of top-down hierarchical management. The absence of a sound regulatory system limits good performance by public as well as private sector operators.

### ***Political challenges***

One of the major challenges to improve the sustainability and resiliency of water systems is lack of political will. The global tendency to focus on short-term policy making does not help to deal with current water related issues that require an investment on long-term benefits. Moreover, in many developed countries, the business-as-usual approach to operations is well accepted and there is no political priority to improve the overall sustainability of the system. In water systems of developing countries, there is often a lack of political leadership and commitment to allocate national resources to the sector or to undertake reforms necessary to provide basic water supply and sanitation for everybody. Similar situations exist in other water-related sectors, such as agriculture, health and forestry.

### ***Financial challenges***

Expanding access to water requires financial resources for extension, rehabilitation, maintenance and operation. This requires huge investment in the future. For the developed countries, the water utilities are financially self-sufficient and might manage the required investment by themselves or with support from the local government. Developing countries where water utilities are financially weak and dependent on the government budget will face further challenges in the future. Poverty will be also in future a major impediment to increasing access to water services. New financial models and cost-benefit analyses are required that ensure self-sufficiency and sustainable water use for multiple users.

### ***Information challenges***

In many Member States, particularly in developing countries, the quantity and quality of hydrological data have been deteriorating due to lack of maintenance and development of hydrological networks. In order to address the current and future water resources challenges, it is imperative to drastically improve the monitoring of hydrological variables at various levels (local, national, regional). Hydrological decision making tools should be based on sound and up to date hydrological sciences derived from appropriate technologies and from good quality data/information. On an opposite note, the proliferation of information, in particular over the internet, on many occasions makes it difficult for the inexperienced professional or manager to distinguish between adequate, real, good quality, and scientifically based information and inadequate, fictitious, bad quality and non-scientifically proven information. The latter poses a major challenge to the water community and calls for the structuring of a solid clearing house mechanism under the guidance and coordination of experienced practitioners and scientists.

### ***Future change pressures***

Our ability to manage sustainable water systems will be further impeded by a range of dynamic global and regional change pressures. The most important pressures include: population growth and urbanization, deterioration of infrastructure systems, socio-economic changes, water quality and new emerging contaminants and climate.

**Population growth and urbanization:** Over the next 40 years, approximately 800,000 new urban residents will be added every week to existing and new cities around the world. The majority of urban population growth will occur in smaller cities and towns particularly in lower and middle-income countries, averaging 2.3% per year, with a doubling time of 30 years. Population growth and rapid urbanization will create pressures on water resources, will increase the challenges to provide safe water supply and basic sanitation and will have tremendous impact on the natural environment.

**Deterioration of infrastructure:** In many parts of the world (including Europe and USA) key parts of the water infrastructure systems are over 100 years old. Therefore, the cost of rehabilitation of water infrastructure system is increasing substantially. For example, European cities are spending in the order of 5 billion Euros per year for wastewater network rehabilitation. Infrastructure

deterioration will impact the public health, environment and institutions in various ways. Deteriorating pipes in cities and irrigation channels in the country side have higher rate of leakage resulting in higher water losses. In addition in particular in cities, this will create higher chance of cross-contamination of drinking water and the outbreak of water-borne diseases. Furthermore rising costs of maintenance and operation as well as frequent rehabilitation of the water infrastructure will increase the costs of the production and impact on the financial situation of utilities and other water management agencies.

**Socio-economic changes:** Many developing countries (e.g. in China, Brazil, India, South Africa) have high economic growth rates expected to continue over the coming decades. This raising living standard will lead to significant increases in demand for resources; increased waste generation and emissions, and increased risk of conflict over resource shortages. Managing the limited resources to meet the growing demand of the future will be challenging due to change in socio-economic changes.

**Emerging contaminants:** With advances in science and technology, knowledge of new contaminants and their consequences on human health and the environment has developed. Several emerging contaminants (EDCs, PhACs, and disinfectant resistant microorganisms) have been identified, which cause public and environmental health concerns. The conventional treatment technologies are not able to remove most of the emerging contaminants. Advanced treatment technologies such as advanced oxidation and disinfection processes, (ozonation, peroxide oxidation, and combinations of UV/ozone/peroxide), membrane based technologies (micro, ultra-, nano-membranes and reverse osmosis) and natural treatment systems alone or in combination with advanced technologies need to be considered.

**Climate:** The global climate variations (extreme events like floods and droughts) will affect the water availability and water quality in the future. The consequences of flood and drought frequencies are likely to increase in many regions, although the amount of increase for any given climate scenario is uncertain and impacts will vary among cities. In addition, potential sea level rise will produce multiple challenges like flood risks; salt-water intrusion in aquifers; loss of wet lands; and loss of coastal infrastructure.

## **OPPORTUNITIES**

Although the challenges for water systems are daunting, there are some opportunities that can be tapped effectively to transform unsustainable water systems to sustainable one. Some of the key opportunities include: strategic planning processes, integrated water management, sustainable, flexible and resilient technologies, emerging economic development, emerging urban centres in developing countries and green economy.

For UNESCO, this IHP phase VIII (2014-2021) will coincide with the fiftieth anniversary of UNESCO's international hydrological initiatives, the International Hydrological Decade (1964-1974) and the fortieth anniversary of the IHP (1975-2014). Indeed the opportunity should be used to commemorate the two anniversaries and to mobilize UNESCO Member States and the international hydrological science community to advance the study of hydrological change to address modern hydrological and water resources challenges.

### ***Strategic planning process***

An opportunity to develop a long-term agenda for water management at various levels is provided by the concept of strategic planning. A strategic plan provides a long-term perspective (15-40 years) for the development of water systems. The process provides a broader view including all aspects of the water system. It considers aspects that were traditionally not considered the responsibility of the water sector, such as energy and urban planning in the cities, or global market trends and

emigration in the rural areas. The strategic planning process has three subsequent phases: visioning, development of plausible scenarios, and strategies selection to achieve the vision. The strategic planning process involves broad stakeholder participation that can drive towards sustainability.

### ***Integrated water resources management***

Integrated water resources management (IWRM) is a process which promotes the integrated management of water resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of ecosystems. IWRM incorporates all parts of the water cycle and recognizes them as integrated systems while considering water demands for residential, industrial, agricultural and ecological consumptions. IWRM recognizes and incorporates the interactions between the system and the ecosystems. IWRM offers considerable benefits as a method to implement adaptation to global change. The approach of IWRM emerged based on experience that sub-optimal outcomes have been achieved by traditional approaches. For instance, in urban areas, in contrast to the conventional approach, IWRM takes a comprehensive perspective to urban water services, viewing water supply, storm water and wastewater as components of an integrated infrastructure system. Furthermore IWRM recognizes that the physical system sits within an organizational framework. Thus, by employing the IWRM practice, overall system optimization can be achieved.

### ***Sustainable, flexible and resilient technologies***

Most future change pressures are associated with severe uncertainties, resulting in difficulties in predicting the magnitude, directions and intensities of their impacts. A response to the future uncertainties is to provide a flexible and adaptable design for water systems. In urban areas, one approach promoting "security through diversity," includes options for wastewater reclamation/reuse, and a combination of end-use efficiencies, system efficiencies and storage innovations in the urban water system. Innovative technologies for the recycling of wastewater will ensure better access to safe water, reduced vulnerability to extremes and increased adaptive capacity. Other options include small-scale decentralized urban drainage systems (SUDS, LID) that have the ability to respond more flexibly to changes in boundary conditions.

### ***Emerging economic development***

The world Gross Domestic Product (GDP) has increased 3% a year since 1975. However, this increase is not equally distributed across the world. China had the highest economic growth with average GDP growth of 10.20% a year in year 2000 to 2008. Other countries such as, India (7.40%), Brazil (3.60%), Russia (6.50%), South Africa (4.10%) and USA (2.20%) have also shown high economic development within the same period. Economic growth provides raising standards of living and improved quality of life and the economic resources required for the future development of the water systems.

### ***Emerging urban centres in developing countries***

In many developing countries there is a high rate of urbanization. Most of the urban growth takes place in small towns and cities (population from 5000 to 10000) as well as emerging villages and towns growing into cities. Emerging towns and villages generally have no legacy infrastructure or institution. Therefore these emerging towns provide unique opportunities to do things differently and to implement innovative urban water management approaches. These towns offer a window of opportunity to implement radically different urban water management system through the use of innovative technologies and institutional arrangements.

### ***Green Economy***

The green economy aspires to improve human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. Sustainable development emphasizes a holistic, equitable and far-sighted approach to decision-making at all levels. It emphasizes not just strong economic performance but intra-generational and intergenerational equity. It rests on integration and a balanced consideration of social, economic and environmental goals and objectives in both public and private decision-making (Rio+20 2012 UN Conference on Sustainable Development). Green economy is characterized by substantially increased investments in economic sectors that enhance the earth's natural capital or reduce ecological scarcities and environmental risks. These sectors include renewable energy, low-carbon transport, energy-efficient buildings, clean technologies, improved waste management, improved freshwater provision, sustainable agriculture and forest management, as well as sustainable fisheries. These investments are driven by or supported by national policy reforms and market infrastructure. From the perspective of green economy all urban water flows (drinking water, wastewater, storm water including solid waste) are viewed as economic goods and their proper handling and utilization have cost implications. As much as costs are incurred in managing them, recovery plans must be incorporated. It is therefore important to embrace a holistic view of water management to reduce costs of operation and to maximize benefits by exploiting the opportunities for reclamation and reuse. Hence different resources can be tapped from waste streams including energy (from solid biomass and liquid waste), nutrients (phosphorus and nitrogen) and reclaimed water.

## **CHAPTER 4: TRANSITION FROM PHASE VII TO PHASE VIII: ASSURING CONTINUITY WHILE ADDRESSING NEW CHALLENGES**

### **DEFINING IHP-VIII PRIORITIES**

To deal with all the complexity and the rapid environmental changes (population, climate change, land use change, globalization, etc.), in the context of the Eighth Phase of IHP, a holistic approach integrating population, ecosystems, water, culture and economy is envisioned. In order to define priorities for IHP-VIII, a series of consultations took place with Member States to identify regional needs and priorities for hydrological research, water resource management and education. A large number of Member States participated in the process and pointed to water related disasters, climate/hydrological variability, water scarcity, water quality and IWRM as being particularly important areas for attaining **water security** where hydrological research, water resource management and education are critically needed. A high degree of connectivity between different topical areas is noted, i.e., in relation to water security, proper understanding of the groundwater systems and adoption of appropriate management policies and tools for protecting and managing groundwater were considered important together with knowledge on conjunctive groundwater-surface water management in an IWRM approach that includes ecosystems and environmental flows. Also, water quality, ecohydrology and urban/industrial water management were found important. The overall analysis of the comments made by Member States pointed to the importance of addressing water security to respond to local, regional and global challenges.

The input from most Member States indicated that IWRM is an important cross-cutting area in research, water management and education, but several member states also requested assistance for catchment-based water allocations and the development of water management policies consistent with transboundary water resources. Indeed, research on water security is urgently needed to avoid conflicts and enhance peace and stability. The need for considering integrated coastal zone and land hydrological management in a climate change context were also addressed by some member states, and in relation to global hydrology, IHP was urged to work for the maintenance of long-term hydrological and ecosystem monitor networks, and to advance the use of remote sensing techniques. Several member states considered it important to promote the IWRM

approach and to include in this approach socio-economic, legal and environmental aspects to qualify impacts that arise from global changes such as population growth and urbanization. The Member States specifically stressed the need for research in social, behavioral, and economic sciences to provide the understanding and tools for participatory governance in facing the different challenges.

## **FRAMING IHP-VIII**

Clearly, in order to be coherent with the global challenges and the needs expressed by member states, IHP-VIII must continue to have a scientific basis that further encompasses holistic management and policy-oriented components that integrate the social, economic, and cultural dimensions of water. Over the last two phases, IHP developed into a broad-based science programme concerned with ecosystems, education, water resources management and capacity building. A new challenge to IHP is to better understand and represent land use, populations, including indigenous peoples, and the role of human behavior and cultural beliefs and attitudes toward water resources and its management. The impact and sensitivity of human beliefs and their behaviors and activities should be better integrated into water management tools and models through social learning. Social learning emphasizes the behavioral processes of learning and the reciprocal teaching roles of scientists and decision-makers. This process has become essential to hydrological decision-making and needs to be given adequate attention in IHP VIII along with the development and implementation of other innovative technologies.

IHP already has various solidly grounded projects and programmes established to respond to Member States water-related needs and priority, as enumerated in the previous chapters. The continuation of these will be considered within IHP-VIII to ensure continuity while also responding to new challenges. In order to advance the development and implementation of IHP-VIII objectives, the development of the new programmatic phase draws on the lessons learned through the ongoing programmes and projects. Indeed, the experience derived from existing programmes and projects have demonstrated that implementation of scientific water management relies to a large extent on how water problems are framed and by whom, the nature of the relationships between scientists, water managers and planners, policy makers, and the water stakeholder organizations they work with, and on how effectively water policy and regulations support the planning and management of water as a system. By identifying this social framework underlying water governance, decision and policy-makers can incorporate cultural values and ideals, traditional and institutionalized formal and informal social practices such as language rules, class and ethnic views, religious rituals and historical basis for policy choices and legal rules. In the tradition of ongoing IHP programmes and projects, translational science is to be used to improve the link between scientists, policy makers and water managers and to support policy-making and decision-taking processes related to water issues at local, regional and national levels.

## **ASSURING CONTINUITY OF IHP PROGRAMMES AND PROJECTS WHILE ALSO RESPONDING TO NEW CHALLENGES**

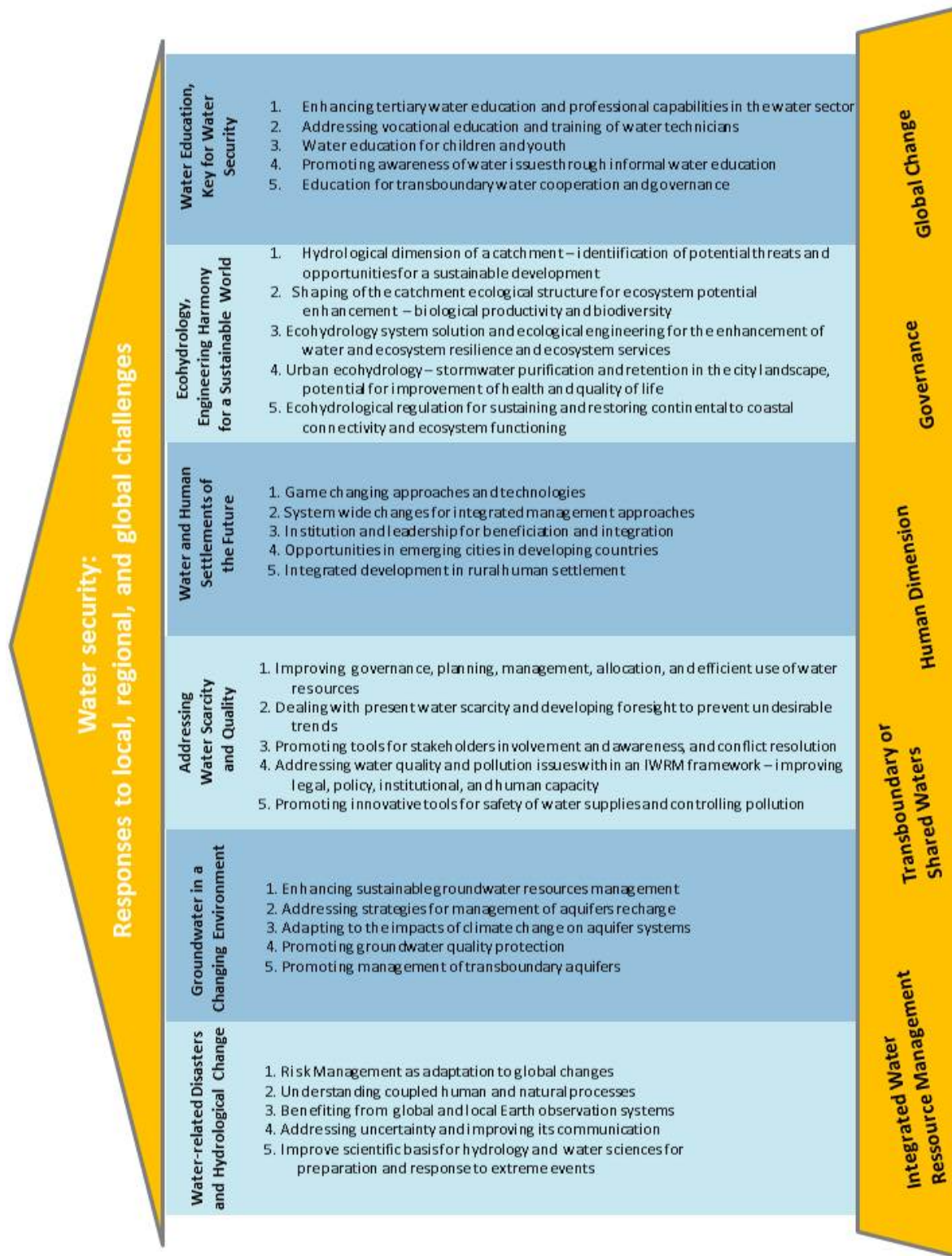
IHP-VIII addresses the overarching theme: ***Water security: Responses to local, regional, and global challenges***. This phase has been designed and will be implemented through a progressive transition from phase VII and by capitalizing on the lessons learned from phase VI, which has just been evaluated, and the results achieved during previous phases of the programme. Within the context of water security, the themes of IHP-VIII address managing water scarcity, water quality and pollution control; adaptation to the impacts of global change and natural disasters on water resources; management and protection policy of groundwater resources for sustainable living and poverty reduction in developing countries and in arid and semi-arid regions and small islands; integration of catchment scale ecohydrological concepts and processes in advanced water

management models; management of water resources for human settlements of the future; and water education as a key element to attain water security. In addition to the themes, this phase has considered certain cross-cutting issues including IWRM, transboundary or shared waters, global change, and the human dimension and governance of water.

Building on the lessons learned from IHP VI and experience gained from the current IHP phase, the implementation of IHP-VIII will require an adaptive approach by region and strong coordination among the IHP family at all levels (Council, National IHP Committees, Centres, Chairs, regional consultation units, etc.). The UNESCO field reform, which is expected to lead to the creation of various UNESCO multi-sectorial regional offices with all the five sectors represented, will impact the implementation of IHP in the different regions. To keep the regional dimension of this hydrological programme, it is imperative to put in place a coordination mechanism among the new multi-sector regional offices within the same UNESCO region. For example, in the Africa region where there will be five (5) multi-sectorial regional offices, effective coordination of IHP activities in the region will require networked communication and planning among the five offices, headquarters, national IHP committees and UNESCO water centres. This coordination should be done by a regional hydrologist posted at one of the five regional offices, and who will coordinate IHP activities in collaboration with other science specialists posted at the regional offices. This new structure, particularly in Africa, provides an opportunity to strengthen IHP partnership with the water units or centres of the Regional Economic Communities and to align interventions with the priorities of the region and different sub-regions. Worldwide, the IHP regional coordination mechanism in the different regions should be strengthened by considering all the IHP family, including national committees, centres, chairs, networks, and programme committees. Special attention should be given to strengthen the involvement of national IHP committees in the implementation of the IHP-VIII.



# CHAPTER 5: THE THEMES AND FOCAL AREAS OF PHASE VIII



## **THEME 1: WATER-RELATED DISASTERS AND HYDROLOGICAL CHANGE**

### ***Background and Challenges***

Human activities have disrupted the natural hydrological and ecological regimes. In fact, the societal and environmental challenges linked to water-related issues are staggering in many cases. More specifically, the number of fatalities as well as the economic damages caused by water-related disasters, such as floods and droughts landslides and land subsidence is dramatically increasing worldwide, mainly as a result of increased population living in areas vulnerable to water-related disasters.

The most important global driver that will significantly change water-related risks in the near future is population growth and its spatial and temporal dynamics. Other drivers, such as land-use changes, urbanization, migration patterns, energy issues, food production, are derived from population change and economic development. In addition, climate change and variability will likely exacerbate the risk with more uncertainties.

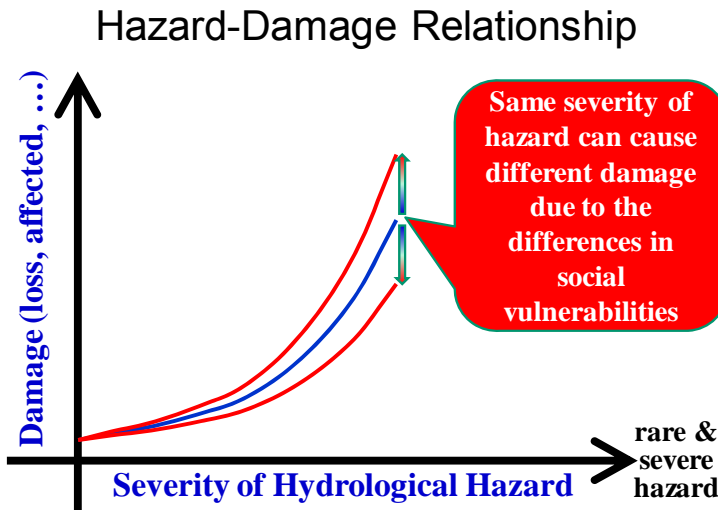
The great challenge for the hydrological community is to identify appropriate and timely adaptation measures in a continuously changing environment. To this end, the main scientific gaps are: i) incomplete understanding of hydrological processes and links with atmosphere/biosphere/human society; ii) appropriate techniques for data integration and/or assimilation, iii) scaling and heterogeneity issues; iv) capabilities to predict hydrological processes and their interactions and feedbacks with socio-ecological systems; v) uncertainty estimation, communication, and incorporation into adaptive resource management decision-making. In addition, our capabilities to make predictions in ungauged basins (PUB) should be further enhanced. Finally, there is a need for being more active in transferring knowledge to policy and decision makers, making certain that decisions take into account the best available knowledge.

### ***Focal Area 1.1: Risk management as adaptation to global changes***

#### **Overall Objectives**

The number of human losses and economic damages linked to human practices has been exacerbated by water-related extreme events. Water-related risk might further increase for a number of reasons. On the one hand, the probability of extreme events which cause high impacts to society is expected to increase because of human activities (e.g. deforestation, river draining, reservoir storage and release, and embankment) and/or as a result of climate variability and change. On the other hand, increasing population and economic growth lead to intensive urbanization, often in flood prone areas. Poor water governance coupled with lack of adequate emergency management institutions and infrastructures reduce society's capacity to cope with extreme events and therefore increase the risk to life and property. Thus, risk management should be improved.

There remains a big gap between the relatively accurate estimates by latest hydrological models and the information required to support decision making based on an evaluation of risk. The relationship between flow volume or rain intensity and expected damages, such as number of casualties, economic losses, and affected area/population, are critical but poorly studied. There is a need to establish methodologies to assess risk, considering the hydro-climatological and social conditions of the area of concern. Integrating pilot case studies on hazard-damage relationships on local/regional scales and developing hazard-damage relationships are essential to providing risk management tools for water managers and policy makers.



Relationship between the damage caused by hydrological extremes and the severity of the event

Risk communication and stakeholder participation have emerged in recent years as an integral part of strategies for managing water-related risks. The aim of risk communication is to reduce exposure to risk and build resilience and resistance to hazards by enhancing the public's perceptions of risks, thus influencing behavior in response to them. Risk communication is both a means to facilitate the adoption of risk reduction/prevention measures and part of the measures themselves (especially early warning, risk mapping and land planning) and brings social benefits such as capacity building and trust. Finally, involving informed stakeholders (with access to key information) in the various stages of participatory planning will also result in more socially robust and accepted mitigation measures.

### Specific Objectives

- Improve understanding and promotion of an approach to flood risk management based on the idea of "living with floods" instead of "fighting floods" (e.g. IFI).
- Further research and develop early warning systems that integrate enhanced monitoring capability and hydrological modeling of socio-ecological systems, which consist of natural and anthropogenic water cycles, to operationally support IWRM.
- Compile, share, and analyze data on socio-economic damages due to water-related hazards, taking into consideration the magnitude of the hydrological hazard and the social vulnerabilities.
- Support Member States in developing a culture of resilience to water-related disasters and risk treatment.
- Develop the knowledge (memory) of past disasters by improving communication and understanding of the changing nature of hazards.
- Support cooperation among Member States and with international organizations to advance vulnerability studies and adaptation actions related to climate change

### ***Focal Area 1.2: Understanding coupled human and natural processes***

#### **Overall Objectives**

The study of hydrological extremes should consider that humans are part of the hydrologic system, both as agents of change and as beneficiaries of ecosystem services. While there have been

significant advances in coupling hydrologic and biogeophysical models over the past decade, these advances remain inaccessible to resource management decision-makers and other water sector professionals. With most river basins being no longer “natural” as humans live and interact with the continuously changing hydrologic system, there remains a need for better understanding of the coupled human-ecosystems.

### **Specific Objectives**

- Implement integrated modeling of social ecological systems (SES) in water resources management decision making processes.
- Improve understanding of the processes in coupled hydrological, biogeochemical, and anthropogenic systems across hydrological domains and social systems both in models and in water education.
- Promote innovative, holistic approaches to education and capacity development.

### ***Focal Area 1.3: Benefiting from global and local Earth observation systems***

#### **Overall Objectives**

Most of the world's river basins and aquifer systems are poorly gauged or completely ungauged. It is essential to strengthen the hydrological monitoring network, which is currently declining. A positive experience in this context is offered by various IHP research programmes (e.g. FRIEND, ISARM, among others). The international community should take advantage from existing large scale river flow archives which are crucial to advance hydrological science and operational issues. However, resources need to be increased to promote and implement open data sharing.

Remote sensing data includes data obtained through satellites and other airborne devices such as airplanes or balloons. These data are used more and more in hydrology. Globally and freely available space-borne data (e.g. SRTM and all current and historical Landsat data) provide the only information readily available, especially in developing countries that lack in situ hydrological monitoring networks, and can remove an obstacle to the application of hydrological models for global and regional predictions. In this context, the UNESCO-ESA TIGER initiative, which is focusing on the use of space technology for water resource management in Africa, is an encouraging example. The Global Observing System (GEO) provides an important set of data to the water community in general. However, the potential of remote sensing techniques to monitor hydrological extremes such as floods and droughts, to monitor water quality, and to support hydrological models is not yet entirely explored nor is it adequately used. In addition, there is a need for improved frameworks to assimilate or integrate remote sensing data into hydrological modeling systems. Having sufficient ground truth information against which remote sensing algorithms can be validated and improved is also critical to effective measurement of water resources. New data sources, such as satellite remote sensing, wireless sensors, acoustic Doppler profilers, and radar are triggering the need for continued training.

#### **Specific Objectives**

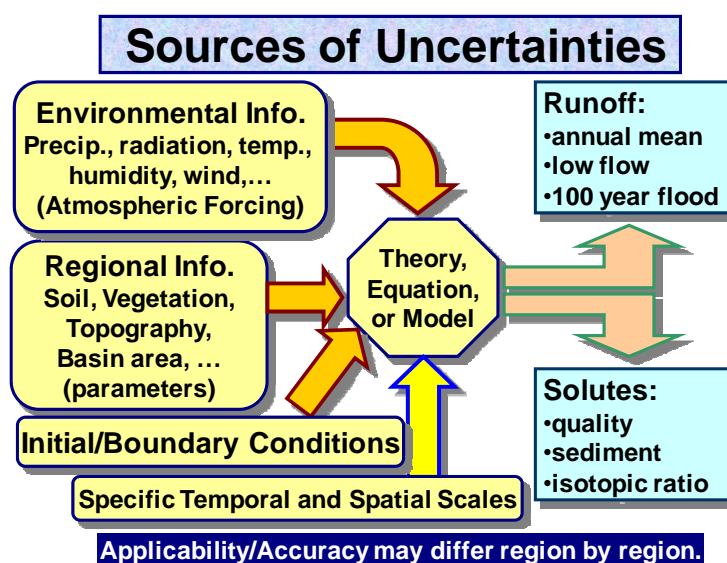
- Adapt models to the continuously changing hydrology, remote sensing and in situ data availability, and to the different needs of water managers.
- Support actions aimed to increase availability of hydrological data in near real time coming from remote sensing and in situ monitors to enable a more integrated approach to continuously calibrate/update models and water management

- Develop new analytical methods, such as sequential processing of data and diagnostic evaluation of model consistency or data assimilation and other quality-assurance tests of real-time data.
- Share experiences with data platforms to facilitate more rapid model adaptation and increase monitoring in critical areas.

### ***Focal Area 1.4: Addressing uncertainty and improving its communication***

#### **Overall Objectives**

There is increasing interest in assessing uncertainty in hydrology and analyzing its possible effects on hydrological modeling and prediction. It is important to communicate uncertainty to those who use the results of hydrologic modeling, for example, in modeling streamflow with little to no in situ data. Nevertheless, environmental agencies, river basin authorities and engineering consultancies rarely apply recent advances in uncertainty analysis and probabilistic mapping of water-related hazards/risks.



Schematic representation of sources of uncertainty for water resources

While the complexity of uncertainty analysis methods may have hindered its practical application, the development of clear guidance on methods and applications will go long way in facilitating such application. IHP, through its ability to mobilize scientific expertise in assisting Member States can contribute and lead the efforts through its various initiatives, such as IFI.

#### **Specific Objectives**

- Adopt consistent terminology and systematic approaches and guidelines for uncertainty estimation.
- Research how the uncertainties of water-related risk maps are understood, communicated, and then responded to in different institutional settings.
- Develop clear guidelines, aimed at water managers, for uncertainty estimation and probabilistic mapping of water-related risks.

- Encourage the application of recent advances in uncertainty analysis and probabilistic mapping of water-related hazards and risks among government agencies, river basin authorities, and engineering consultancies.
- Encourage governmental flexibility in developing new standards and regulations in response to climate variability and changes.

### ***Focal Area 1.5 – Improve scientific basis for hydrology and water sciences for preparation and response to extreme hydrological events***

#### **Overall Objectives**

The negative consequences of extreme hydrological events have increased due to the increase of human settlements in disaster prone areas. Many people around the world are impacted every year by water-related disasters. Flood frequency statistics have changed in recent years due to the variations in climate and land use changes. These need to be revised to raise the resilience of hydraulic structures during flood events. For example, in Francophone sub-Saharan Africa countries, engineers and managers have been using tools and guidelines developed since the 60-70s for the design of hydraulic infrastructures despite the huge ecological and climate variability observed.

IHP VIII encourages the development of scientific and methodological basis for hydrology and water sciences to prepare and respond to extreme events. Research in river flow formation processes, methods of hydrological calculations and forecasting, mathematical and numerical modeling and improvements to the theory of channel processes and sedimentation are among the research topics suggested by Member States.

#### **Specific Objectives**

- Support and expand scientific research and development of methodological basis for hydrology and water sciences
- Document recent hazards induced by extreme hydrological events and share lessons learned within the water community.
- Promote among water professionals and managers the understanding of probabilistic and uncertainty analysis of extreme events.
- Reset design standards of hydraulic structures considering the variations in climate and land use changes.

## **THEME 2: GROUNDWATER IN A CHANGING ENVIRONMENT**

### ***Background and Challenges***

Groundwater is a significant component of the hydrogeological cycle and aquifers are an important hydrological unit. Globally, groundwater represents 98 % of the Earth's unfrozen freshwater. In nature, groundwater drives many geological and geochemical processes and sustains various ecological functions and services. Groundwater should be integrated with economic, social and environmental dimensions of water resources. Many people depend upon groundwater for potable water and for ensuring food security and sustainable living. Groundwater may also be considered a safe source of drinking water in arid and semi-arid regions and small islands and in emergency situations.

The use of groundwater has significantly increased over the last 50 years due to its widespread occurrence, high reliability during drought seasons, mostly good quality, major advances in

hydrogeological knowledge, development of modern drilling and pumping technologies and generally modest development costs. In previous IHP phases, groundwater programmes and projects improved knowledge of groundwater and aquifers worldwide. Collaboration with the GEF as well as with other UN organizations, scientific institutions and universities contributed to improvement of the knowledge of groundwater and its resources and aquifers worldwide. As a result of these collaborative scientific activities, a fairly good understanding exists about shallow aquifers, methods of groundwater resources assessment and development, artificial recharge, groundwater pollution, and methodology of hydrogeological mapping. However, we still face many challenges: the complexity of aquifer systems, the increasing global risk to groundwater depletion, quality deterioration and pollution, growing demand for groundwater resources for drinking and other uses, potential influence of climate change on groundwater system, and resilience of communities and populations dependent on groundwater sources. These challenges call for comprehensive research and studies, implementation of new science-based methodologies and endorsement of principles for integrated management and environmentally sound protection of groundwater resources.

### ***Focal Area 2.1 - Enhancing sustainable groundwater resources management***

#### **Overall Objectives**

This focal area addresses the safety and reliability of groundwater resources as a vital necessity for human life, social and economic development, poverty alleviation and healthy functioning ecosystems. Sustainable groundwater management is based on holistic, multidisciplinary and environmentally sound approaches and studies that include groundwater quantity and quality, relationships between groundwater and surface water and groundwater dependent ecosystems and land use planning and practices. These studies take into consideration ethical, religious and cultural traditions of society and should be based on a participatory approach involving decision and policy makers, water scientists and managers, planners, water stakeholders and general public. This focal area addresses quantitative attributes of groundwater resources management and protection while groundwater quality attributes are addressed in Focal area 2.4.

Sustainable groundwater development and resource management very much depend on knowledge of aquifer systems, groundwater recharge and discharge rates and groundwater storage. Demographic changes and population growth in several regions and related increases in groundwater demand for drinking and other uses as well as influence of changing climatic conditions on groundwater are other factors which have to be studied to ensure sustainable development and management of groundwater resources for the future needs. Specific attention should be also given to the management of non-renewable groundwater resources whose exploitation always leads to storage reduction.

#### **Specific Objectives**

- Promote measures to address the principles of sustainable management of groundwater resources and incorporate them into National Water Master Plans as a basic country document for integrated management and environmentally sound protection of water resources.
- Address methods for sound development, exploitation and protection of groundwater resources to minimize social and ecological side-effects on populations and water supply systems and propose appropriate measures for rehabilitation / replenishment of depleted aquifers.
- Manage and balance competing demands for groundwater resources especially in arid and semi-arid regions to reduce risks associated with drought impact by use of relevant models and considering limited availability of groundwater data in developing countries.

- Develop new groundwater resources maps and visualizations at various scales, related guidelines, standards, and methods for the assessment, mapping and presentation of groundwater resources in areal extent and three-dimensional nature (WHYMAP).
- Strengthen groundwater governance policy and water user rights in emergency situations (natural disasters, human induced pollution events) and increase public awareness in the management of emergency groundwater resources based on historical experience and knowledge.

## ***Focal Area 2.2 - Addressing strategies for management of aquifers recharge***

### **Overall Objectives**

This focal area addresses the security and quality of water supplies in water scarce areas and aims to improve adaptation to climate change. A wide range of methods for enhancing groundwater recharge have been developed and applied over the centuries, depending on source, availability and quality of water, geological and hydrogeological conditions, uses of recovered water, socio-economic conditions, governance and institutional frameworks and public awareness and participation in water management. Considering the benefits of groundwater recharge management and its potential to be a significant contributor to the MDGs, the Programme Strategies for Managed Aquifer Recharge (MAR) in semi-arid regions was initiated in 2002 within UNESCO-IHP in cooperation with IAH. Its aims is to expand water resources and improve water quality in ways that are appropriate, environmentally sustainable, technically viable, economical and socially desirable. However, there is still room to increase knowledge and capacities for managing aquifer recharge, water harvesting and waste water recycling using combination of different engineering treatment techniques and natural attenuation processes. Particularly in arid and semi-arid regions, MAR has the potential to contribute to the MDG for drinking water more economically than other alternatives. MAR programme can also be highly effective in creating new water resources and increases also the security of drinking water supplies under climate change and population growth.

### **Specific Objectives**

- Integrate managed aquifer recharge into IWRM to address effects of locally changing climate, population and food production.
- Develop and apply methods to assess impacts of recharge structures on water availability and quality, social and economic resilience and local ecosystems with special focus on appropriate MAR methodologies and techniques for conservation and augmentation of safe drinking water supplies in developing countries in arid and semi-arid regions.
- Evaluate the risks and benefits of recycling of appropriately treated urban waste and storm water for aquifer recharge to produce safe irrigation or drinking water supplies.
- Enhance governance capacities and institutional and legal frameworks to aid effective MAR Programme implementation.
- Develop a scientific basis for the prevention and management of clogging in recharge systems to increase confidence in MAR for sustaining the quantity of water supplies via aquifers replenishment and improve measurement methods, models, knowledge of biochemical processes and fate of pathogens and organics in MAR systems.

## ***Focal Area 2.3 - Adapting to the impacts of climate change on aquifer systems***

### **Overall Objectives**



This focal area seeks to assess the medium and long-term impacts of climate change on groundwater resources and establish relevant mitigation and adaptation strategies on the global, regional and local scales. Few studies have been done until recently on the potential impact of climate change on groundwater referencing its relation to surface water. The most important direct effect of climate change on groundwater is associated with recharge patterns. Spatial and temporal distribution of precipitation, air temperature, evapotranspiration, soil moisture, groundwater levels and response time of aquifers are the main natural factors controlling groundwater recharge in different climatic zones. Reaction of deep, non-renewable and fossil aquifers to climate change impacts will last centuries or millennia; reaction of shallow, karst and coastal aquifers can last in case of groundwater recharge only weeks, months or years.

Models for prediction and quantification of groundwater systems response to the impact of climate change are facing several uncertainties due to lack of a consistent soil and groundwater global dataset. To calibrate hydrological models for simulation of spatially and temporally changing groundwater recharge, discharge and storage and inclusion of a groundwater component into land surface models require improvements in terrestrial and satellite based groundwater monitoring and monitoring data assessment and management. Coastal aquifers prone to depletion and accompanying land-level lowering contributing to sea-level rise need particular attention.

The potential impacts of climate change on groundwater quantity and quality have to be analyzed and quantified in terms of their social, economic and environmental effects on and risks for population and groundwater dependent ecosystems. Several activities will be carried out under GRAPHIC programme whose continuation in IHP VIII has been proposed.

### **Specific Objectives**

- Identify and evaluate the potential influence of climate change on different types of aquifers under different climatic, geographical, hydrogeological and hydrochemical conditions and provide relevant data for appropriate models for predicting and assessing climate change impacts on specific aquifer systems (e.g. shallow, coastal, karstic, deep, non-renewable).
- Increase public awareness about importance and vulnerability of groundwater resources and propose adaptation measures in the context of climate change influence on aquifers in developing countries, preferably in arid and semi-arid regions.
- Promote the increase of groundwater storage in aquifers in order to create more water security in view of potential climate change impact and conduct case studies preferably focused on regions regularly affected by droughts.
- Expand and integrate ground and satellite-based monitoring methods in order to better identify climate change impacts on groundwater recharge and storage and provide data for evaluation of paleo, present and future markers of sea water intrusion in coastal aquifers.
- Improve/develop appropriate methodologies and models for predicting and assessing climate change impact on groundwater resources at regional and small islands scales

### ***Focal Area 2.4 1`11– Promoting groundwater quality protection***

#### **Overall Objectives**

This focal area aims to enhance knowledge of groundwater quality and groundwater protection policy. Many Member States included aspects of groundwater quality protection for drinking and other uses in their priorities for IHP VIII.

Establishment and operation of national groundwater quality monitoring networks effectively supports sustainable groundwater quality management, provides valuable data for assessing the

current state of and forecasting trends in groundwater quality and helps to clarify and analyze the extent of natural processes and human impacts on groundwater system in time and space. Hydrochemical maps depicting groundwater chemical types and quality are useful tools for regulatory and managerial purposes and help planners make informed, environmentally sound decisions regarding groundwater protection and quality conservation. Additional research is needed in the modeling of hydro-geochemical processes and in the study of the chemical and isotopic evolution of groundwater. This focal area addresses groundwater quality management with the view to improving groundwater pollution prevention policy, mitigate pollution risk and enhance effective in situ pollution remediation techniques.

### **Specific objectives**

- Propose basic principles for sustainable groundwater quality management and groundwater protection policy with special focus on developing countries and link sustainable sanitation with groundwater protection in order to secure the quality of groundwater resources for current and future uses.
- Outline the basic criteria for the assessment of groundwater quality and vulnerability in regions repeatedly affected by climatic, hydrological and geological extremes (GWES).
- Improve numerical and statistical models for groundwater quality and hydrochemical evaluation and mathematical simulation models describing pollutants transport and transformation processes that take place in the soil and groundwater system.
- Strengthen national groundwater quality monitoring networks and site specific monitoring systems around pollution sources, in public groundwater supplies protection zones and in groundwater dependent ecosystems.
- Increase support for the study of the origin, behavior, and processes occurring in groundwater environments polluted by hazardous substances of natural origin (arsenic, fluoride) or by specific organic chemicals (e.g. pharmaceutical products) and propose cost-effective soil and groundwater pollution remediation techniques..

### ***Focal Area 2.5 - Promoting management of transboundary aquifers***

#### **Overall Objectives**

This focal area will enable Member States to improve their institutions, strengthen professional capacities and develop regulations for the sustainable management and environmentally sound protection of transboundary aquifers. More than half of the large continental aquifers are shared between two or more riparian countries. To compile a world inventory of transboundary aquifers and to develop wise practices and guidance tools concerning shared groundwater resources management UNESCO IHP established the long term ISARM (Internationally Shared Aquifer Resources Management) Programme launched at the 14<sup>th</sup> Session of Intergovernmental Council of the UNESCO IHP (2000). Within the first phase of the UNESCO ISARM programme, UNESCO – IHP provided technical support to the United Nations International Law Commission for the preparation of the draft articles on the Law of Transboundary Aquifers. The UN General Assembly adopted Resolution on the Law of Transboundary Aquifers in December 2008.

Strengthening groundwater monitoring activities of transboundary aquifers and filling their groundwater data gaps are a globally justified task and IHP will provide guidance to establish and promote: policies to encourage and assist organizations involved in the development of groundwater to monitor, record, assess and submit groundwater data and information; GIS databases to facilitate the storage and retrieval of groundwater data for different uses; and institutional and legal frameworks to manage, share and use data on international level.

## Specific Objectives

- Finalize assessment of transboundary aquifers on the world-wide scale including all components of ISARM Programme and develop a global groundwater databases and knowledge-based systems within IGRAC Global Groundwater Monitoring Network Programme to assist Member States set up their own groundwater information services and provide data for periodic assessment of global and regional groundwater resources.
- Implement the UNGA Resolution on the Law of Transboundary Aquifers 63/124.
- Support African countries to improve their cooperation and mutual understanding, strengthen their capacities and develop regulations for the sustainable management of transboundary aquifers.
- Map and evaluate with the support of WHYMAP and IGRAC the relation between international river systems and transboundary aquifers.
- Coordinate activities for parallel UNESCO IHP activities that relate to transboundary aquifers and support other initiatives on transboundary waters such as e.g. the transboundary water programme at the Institute for Water and Watersheds (<http://www.transboundarywaters.orst.edu.index.html>).

## THEME 3: ADDRESSING WATER SCARCITY AND QUALITY

### *Background and challenges*

Water scarcity is a natural as well as a human-induced phenomenon. Although there is enough freshwater on the planet for the world population of about seven billion people, its distribution is uneven in both time and space and a lot of it is wasted, polluted and managed in unsustainable manner. There is no global water scarcity as such but a number of localities and regions in the world are short of water due to the fact that worldwide water use is growing at more than twice the rate of population increase in the last century. About one-fifth (1.2 billion) of the world's 6 billion population, live in areas of physical water scarcity and another one quarter (1.6 billion) of the world's population face economic water shortage due to lack of the infrastructure to take water from rivers and aquifers (UN, 2005). For many countries, water scarcity represents the most pressing challenge to socio-economic and human development at large<sup>2</sup>

Water scarcity is the condition wherein demand for water by all sectors, including the environment, cannot be satisfied fully due to the impact of water use on the supply or quality of water. Water scarcity can be made worse by climate change especially in arid and semi-arid areas, which are already water-stressed. Thus, protection of the world's fresh water resources requires that human impact on the earth's environment and climate be addressed in an integrated manner. Investment in programmes that protect the natural environment, conserve water and use water efficiently is critical.

Water quality degradation contributes to water scarcity. This is a serious and neglected aspect of water resources management. Poor water quality has multiple health and environmental consequences which make the water unfit for use, hence reducing water resources availability. Indeed, water pollution is becoming one of the greatest threats to freshwater availability and re-use. Rapid urbanization, increased agricultural activities, use of fertilizers and pesticides, land degradation, high population densities and poor disposal of waste are affecting available fresh water

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<sup>2</sup> UN, 2005, Water for Life Decade, 2005-2015: Water Scarcity. Available at: <http://www.un.org/waterforlifedecade/scarcity.shtml>.

sources. Water treatment can be expensive. Actions therefore need to be taken to address issues of water scarcity and water quality in particular. IHP can make a significant contribution to understanding and managing water quality in the developing world.

### ***Focal Area 3.1 - Improving governance, planning, management, allocation, and efficient use of water resources***

#### **Overall Objectives**

The way water scarcity issues are addressed impacts upon the achievement of most of the Millennium Development Goals. The increasing significance of water scarcity worldwide calls for increased integration and cooperation to ensure sustainable, efficient and equitable management of scarce water resources, both at international, regional, and local levels. Cooperating on transboundary river and aquifer water uses and optimal allocation of water resources is an important element of water diplomacy. This focal area, therefore promotes catchment-based water resources planning and decision-making, rational allocation of water resources and regulation of water use, and conjunctive use of groundwater and surface water.

#### **Specific Objectives**

- Promote catchment-based water resources planning and decision making, and promote a policy shift towards water demand management and its integration in the policies of the various water use sectors.
- Promote good water governance practice, including shared vision planning and adaptive management to enhance rational water allocation and implement water use policies and regulations.
- Promote sustainable conjunctive use of groundwater and surface water for meeting various needs under changing scarcity conditions and implement adaptation measures to climate change.
- Understand and promote valuation and costing of water as a tool for cost-effective decision making in water resources management.
- Promote water use efficiency in the various water use sectors through traditional and modern technologies.

### ***Focal Area 3.2 - Dealing with present water scarcity and developing foresight to prevent undesirable trends***

#### **Overall Objectives**

New and innovative policies and strategies are needed to address the sustainable management of fresh water resource. The negative impacts of unsustainable water use on human population and ecosystems have created a growing movement toward a greening of water management and law. The goal is to find a balance between water for human and economics-based demands and water for maintaining ecosystem integrity and environment sustainability. This balance entails reconciling the seemingly disparate goals of socio-economic development and environmental protection and conservation. The purpose of this focal area is to predict and plan for water scarcity by developing alternative and non-conventional water resources.

#### **Specific Objectives**

- Predict and plan for water scarcity for a sustainable future through building international and regional consensus on the way of addressing water scarcity, better measure and account for

freshwater, developing and improving predictive water planning and management tools, enhancing water management and sharing during scarcity periods, improving understanding of water-related services and ecosystem needs for water, improving valuation of water, designing schemes in order to live with scarcity in view of the ongoing climate change and exploring new forms of resource management.

- Develop alternative and environmentally and economically sound non-conventional water resources (e.g., desalination and treated wastewater) as well as conventional water augmentation techniques (water transfer, water reuse, water harvesting) through encouraging world-wide use of technologies and successful experiences for enhancing water supply.
- Develop and promote innovative water-saving technologies and tools and enhance their public acceptance as an adaptation measures for scarcity.

### ***Focal Area 3.3 - Promoting tools for stakeholders involvement and awareness and conflict resolution***

#### **Overall Objectives**

Attaining water security requires addressing a range of issues from protection of the environment, coping with water scarcity and climate change, fair pricing of water services, to equitable distribution of water for irrigation, and industrial and household use. International organizations, governments, and local communities should all play a role. Improving the management of water resources and providing access to water for more people cannot be done without investing in water conservation and delivery systems, protecting the earth's ecosystems, conserving water and using water more efficiently. The involvement of stakeholders is therefore a key in achieving the targets and is an important component of good water governance. The overall objectives of this focal area is therefore involvement of stakeholders in sustainable water resources use and management, training, communicating and raising awareness on water scarcity issues and managing conflicts over water resources use under changing human and climatic conditions.

#### **Specific Objectives**

- Engage all stakeholders (NGOs, private sector, local communities, etc.) in sustainable water resources use and management.
- Train, communicate, and raise stakeholders' awareness of water security issues.
- Empower education, universities and research institutes to address issues of water scarcity, including efficient water use and conservation.
- Strengthen education and training in inter-disciplinary policy and decision making for water professionals and decision makers under scarcity conditions.
- Promote and support capacity development for decision makers in managing conflicts over water resources use under scarcity conditions induced by either human activities and/or climatic change.

### ***Focal Area 3.4 - Addressing water quality and pollution issues within an IWRM framework - improving legal, policy, institutional, and human capacity***

#### **Overall Objectives**

The crisis in water pollution is exerting social and economic pressure everywhere in the world and this has been worsened by frequent waves of droughts and hence water shortages, and floods and

hence too much water. In addition, to the recurrent wave of droughts and floods, water pollution is also due to poor management of the wastewater, under-investment, unfair allocation of water, rampant deforestation, and a huge population explosion. Management of the quality of both surface water and groundwater should therefore be integrated with management of the quantity of water as part of implementation of IWRM as well as in planning and management frameworks at local, national and transboundary levels. This focal area therefore aims at improving the understanding and knowledge of the quality of world's water resources for human wellbeing as well as instituting water pollution licensing and enforcement systems for sustainability in order to address water quality and pollution issues.

Furthermore, in the context of IWRM, effective water pollution control and water quality management requires an enabling environment in the form of policy, legal and institutional frameworks. Appropriate water and environmental laws and accompanying regulations such as waste water discharge regulation, environmental impact assessment regulations are key legal and regulatory instruments for governing water allocation, environmental assessment and pollution control and key water resources management activities. Consequently, this focal area also aims at enhancing legal, policy and institutional frameworks for water quality management and building institutional and human capacity in water quality management and water pollution control.

### **Specific Objectives**

- Improve the understanding and knowledge of the quality of world's water resources for human wellbeing through monitoring and assessment of quality of world's water resources, strengthening the knowledge base and information, data management and sharing.
- Assess the current knowledge base and information about water quality to establish management priorities.
- Integrate quality-quantity management and science-based decision making.
- Improve water pollution licensing and enforcement systems for sustainability through developing water quality regulations, guidelines, and standards and promoting their implementation and improving enforcement and compliance to various standards and regulations.
- Enhance legal, policy and institutional frameworks for improved water quality management.
- Build institutional and human capacity in water quality management and water pollution control (strengthen scientific and technical cooperation).

### ***Focal Area 3.5 - Promoting innovative tools for safety of water supplies and controlling pollution***

#### **Overall Objectives**

Water quality issues are becoming more complex because the sources of pollution are often diverse, too many and difficult to monitor and even where the polluters are identified, the water managers lack the necessary authority to enforce compliance to the regulations. The objective of this focal area are developing and promoting new innovative tools for water quality management and pollution control for sustainable livelihoods as well as promoting joint research on particular water quality issues and challenges through an integrated water pollution management framework.

#### **Specific Objectives**

- Develop and promote new innovative tools for water quality management and pollution control.

- Promote joint research on particular water quality issues and challenges through improving the understanding and scientific knowledge on new and emerging pollutants, and monitoring/risk assessment, regulations, control/attenuation.
- Promote integrated water pollution management through prevention, reduction and restoration of polluted water, wastewater management and management of impacts of land-use changes.
- Share research findings and successful experiences in reducing pollution and restoring water quality among managers and others participating in watershed governance.

## **THEME 4: WATER AND HUMAN SETTLEMENTS OF THE FUTURE**

### **Background and challenges**

One of the major challenges of the 21st century is to provide safe drinking water and basic sanitation for all. At present close to 1 billion people lack access to improved water sources, and over 2.6 billion people lack access to basic sanitation – nearly all of these live in cities in developing countries. Today, cities all over the world are facing a range of dynamic regional and global pressures, such as climate change, population growth, deterioration of urban infrastructure systems and more. Due to these pressures cities of the future will experience difficulties in efficiently managing scarcer and less reliable water resources and to provide sufficient sanitation.

In the past urban development pathways have created very complex systems of infrastructure and institutional framework that interact and influence each other. Strategies to build resilient urban water systems must adopt a broader perspective that recognizes the interdependence of the different water systems. Realities on the ground and the challenges of future pressures have made it obvious that business as usual is not the way forward. New approaches for the water management in the city of the future have to be developed. In this respect five focal areas are proposed game changing approaches and technologies, system wide changes for integrated management approaches, institution and leadership for extracting the maximum benefits from water (beneficiation) and integration, opportunities in emerging cities of developing countries, and integrated development in rural human settlement. The case of rural settlements and cities in developing countries merit a special emphasis, including its slums or peri-urban areas that often are the most deprived.

### ***Focal Area 4.1- Game changing approaches and technologies***

#### **Overall Objectives**

The business as usual approaches and traditional technological choice for urban water management will not be able to sufficiently address the many challenges identified in urban center. There is a need for intervention of innovative approaches and technologies in the urban center that ensures resources and costs optimization. Innovative technologies, such as membrane filtration systems, advanced oxidation, hybrid systems of natural and advanced treatment, microbial fuel cells, electrochemical and nano-technology have led to new ways of managing urban water systems through efficient reuse of water and nutrients and the recovery of energy. Important sub-areas within this focal area include: the concept of water machine, consideration of alternative water sources, reinvestigating natural systems as important components of the urban water system and use of smart networks.

Some of the innovative approaches, such as semi-centralized approaches are suited to the concept of water beneficiation (water machine) which aims to extract maximum benefit out of one resource. In this approach a raw material (wastewater of different qualities) flows into the water machine, and generates many products – nutrients, energy, and water – as resources. This has a potential for

green economy with small businesses harvesting different benefits from waste stream. Based on the principle of “all water is good water“ approaches of matching water quality and water use to improve water efficiency are promoted. By employing innovative technologies, reclaimed water can be reused multiple times, through cascading water use approaches for different purposes that require different water quality. Natural systems in an urban context can be used for treatment, resource recovery and buffering of the natural environment. As the fundamental understanding in natural treatment systems (NTSs) is improving, these technologies are being increasingly used to improve water quality for drinking purposes and storm water as well as wastewater treatment for groundwater recharge or safe disposal.

By employing ICT technology and adaptive design approaches smart networks enable urban water systems to be designed, controlled and maintained in a way that allows optimization of water quantity, water quality and the water energy footprint.

The aim of this focal area is to explore the available innovative approaches and game changing technologies that are best suited for resources and cost optimization in urban area.

### **Specific Objectives**

- Take stock of the various existing approaches to urban water management starting from conventional approaches to more distributed approaches, qualifying their performance according to city size and region. Urban water management plans should include long-term funding solutions to build and maintain water and wastewater infrastructure.
- Elaborate on the concept of water-machine within the urban environment typifying the ways in which it could be implemented, the conditions under which this potential can be maximized, and the likely consequences in cities of the developed and developing world, by updating and qualifying the current and potential non-conventional sources or efficiency-enhancing means for providing urban water.
- Promote a fuller understanding of the role of urban groundwater – as a source of water in the conventional sense, but also the risks of uncontrolled extraction of contaminated groundwater under the city itself and of the dynamic character often missed and entrain other risks such as rising water table because of leakage, potential contamination of drinking water when the water table rises above the sewage and/or water supply network.
- Develop a systematic inventory of existing natural systems treatments qualifying their performance and potential in the urban environment, possible direction in the intensifying their application and investigating new approaches, especially those linking to the application of ecohydrology concepts.
- Analyze the state-of-the-art in the design of smart networks applicable to urban water management likely condition in which they will prosper and their potential benefits, especially in cities of developing countries.

### ***Focal Area 4.2 - System wide changes for integrated management approaches***

#### **Overall Objectives**

Integrated urban water management (IUWM) aims to incorporate all parts of the water cycle and recognizes them as integrated systems while considering water demands for residential, industrial, agricultural and ecological consumptions. The approach of IUWM emerged based on experience that sub-optimal outcomes have been achieved by the traditional approach. IUWM provides the opportunity to optimize the whole urban water system and to minimize water consumption, costs and energy. To improve IUWM, a much deeper understanding of the interfaces and



interconnections between the different resources streams in cities in particular the water – energy – food nexus is required.

The game changing technologies previously referred need to be coupled with comprehensive system changes to the urban water system. Despite improvement in the performance and efficiency of the component parts of urban water systems, change is needed at a system-wide level as well. The high-level relationships among water resources, energy, and land use in an urbanizing world have to be recognized. The overall objective of the focal area is to explore integrated approaches that ensure the need for system changes through the integrated management approaches. This comprises five activities: integrated urban water management (IUWM), urban metabolism, flexible and adaptive approaches, water sensitive urban design and transitioning.

### **Specific Objectives**

- Study the potential application of flexible and adaptive design to urban water management, identify promising directions and propose ways and means to develop and apply meaningfully this concept in cities in diverse socio-economic, cultural and physical environments, considering the possible consequences of global changes, including demographics, climate change, land use change, changing consumption patterns and technological advances. The presence of slums and marginal peri-urban areas will be integrated into the analysis considering the attendant institutional, social and economic implications.
- Perform comparative studies of urban metabolism models with significance to urban water management and potential applicability.
- Compile and analyze cases where water sensitive urban design has been applied since its inception over 20 years ago, evaluate the state-of-the-art, including restoration of urban streams, and recommend the relevant applications, particularly in cities of the developing world.
- Identify the characteristics of existing transition models: principles, objectives, scope, and required information; select case studies with description of current and desired scenarios and evaluate results from the application of models, including the possibility of “leapfrogging” to accelerate development, particularly in developing countries.
- Support regional activities and inter-regional cooperation in aspects addresses under this focal area, incorporating relevant regional initiatives such as SWITCH-in-Asia, and the contribution of the regional and international water-related centres under the auspices of UNESCO and of UNESCO-IHE Institute for Water Education.

### ***Focal Area 4.3 - Institution and leadership for beneficiation and integration***

#### **Overall Objectives**

System wide changes and game changing technologies discussed earlier need to be coupled with governance and institutional structures that support their implementation. In addition, there are opportunities of introducing green economy to benefit from the innovations being proposed and further research is required on how best to maximize this. A major challenge is that the urban water practitioners responsible for implementing water infrastructure systems are not educated in a way that encourages systems thinking. Hence, there is a need for innovative curriculum development that supports human settlements of the future.

The overall objective of this focal area is to analyze the governance and institutional aspects of urban water management and propose best practices for different economical and geographical setting of developed and developed countries.

### **Specific Objectives**

- Examine the appropriate level of centralization and decentralization of urban water management according to the prevailing technical considerations and of economies of scale and necessary conditions of autonomy for the decentralized scheme in order to insure viability and effectiveness, considering case studies.
- Develop a conceptual framework of institutional structures conducive to the adoption of more effective management that enables the necessary transitional process and introduction of innovative practices, including effective conflict resolution mechanisms.
- Investigate the current and potential links of effective urban water management to the generation of green growth, including the introduction of water beneficiation processes and the impact of urban agriculture.
- Promote capacity development of a new generation of urban leaders with a wider vision of the role of the city processes with the economy and the interaction between the urban infrastructure for the different urban services, and sensitive to appropriate innovations, placing a special emphasis on urban water management aspects.
- Carry out a survey of current participatory approaches applicable to urban water management and how participating stakeholders can effectively be integrated into the decision-making process and into potential transitioning processes under various environments, and formulate appropriate conclusions.

### ***Focal Area 4.4 -Opportunities in emerging cities in developing countries***

#### **Overall Objectives**

Over the next 40 years, approximately 110,000 new urban residents are added every day to existing and new cities around the world. The majority of urban population growth will not occur in the megacities, but rather in smaller cities and towns particularly in lower and middle income countries. This will mark the second wave of urbanization with just over 50% of humanity living in urban areas today. Currently urban settlements in developing countries are growing five times as fast as those in the developed countries. In Africa the population will soon pass 1 billion people and is expected to reach 2 billion people by 2050 (UN's report, 2009). Population growth and urbanization go together. Population growth increases density and creates higher urban agglomeration.

Those emerging cities have immature infrastructures and institutions which offer a huge opportunity to do things differently. Although the developmental stages are often represented as a model of linear progression, emerging cities can follow trajectories across the continuum and may leapfrog some of the stages based on circumstances. The overall aim of this focal area is to explore transitioning pathways by leapfrogging for emerging cities in developing countries without moving linear trajectory path of traditional urban water management.

#### **Specific Objectives**

- Perform a state-of-the-art review of existing urban water systems in developing countries, their evolution and constraints (physical, technical, institutional, financial, political, social); identify responsible national institutions as well relevant intervening international cooperation institutions, regional and intergovernmental organizations, and NGOs.

- Characterize a representative cross-section of cities regarding size, environmental, social, cultural, institutional and developmental conditions and aspects relevant to urban water management.
- Develop a set of criteria for identifying the cities that may offer favorable conditions for rapid urban water development and of “leapfrogging” to Integrated Urban Water Management and undertake a pilot project in cooperation with the relevant institutions and governments. Identify those elements that lend themselves to replication in developing countries in other regions of the world.
- Organize a series of well-designed events in target countries and sub-regions in order to obtain significant responses from stakeholders to the above activities, to impart capacity building sessions – these would need to be closely coordinated with the local authorities, regional organizations such as AMCOW (African Ministers’ Council on Water), ADB, AFDB, and UN organizations such as UN-Habitat.

### ***Focal Area 4.5 – Integrated development in rural human settlement***

#### **Overall Objectives**

Almost half of humanity, mostly in Asia and Africa, still live in rural areas and are of low income groups. The poor rural population lack access to basic water supply (900 million) and safe sanitation, which result not only in tremendous human health and economic costs but also create gender and other societal inequalities. The majority of rural population in the developing world are illiterate, unskilled and is composed of mainly elderly people, women and children, who do not have resources to support/cope with natural variability and its impacts.

Water supply and sanitation support in rural areas is more challenging due to the settlements location mostly in environmentally fragile areas; development models dominated by diverse cultural values, poor economic condition, and associated cost recovery challenges. In many cases, scattered settlements, dominated by agro-based economy and limited water resources give rise to challenges for infrastructure provision. Most of the existing water infrastructure is decentralized systems (e.g. community water collection point, public stand post, pit latrines and septic tanks in some cases). Such infrastructure systems have also fallen into disrepair due to technical, financial and managerial limitations. Rural population often depend on local water sources (wells, hand pumps, river), which are in many cases contaminated.

The rural people lack access to appropriate, low-cost and locally produced technology for water, sanitation and hygiene needs. The advanced and urban focused technologies will not fit for the rural case. The technologies should also take into account other issues, such as energy efficient and uses of natural treatment systems, which are robust and low cost. The technology should also address the cultural values of rural people in developing countries. The model of public participation in development could be different, to be compatible with local traditions (such as involvement of the elderly, ethnic and community chiefs) while developing water and sanitation technologies in rural areas.

The overall aim of this focal area is to support the development of an integrated development strategy for ensuring sustainable water security and sanitation in rural area settlements. It consists of four suggested activities as presented below.

#### **Specific Objectives**

- Identify appropriate awareness raising programme for water security and safe sanitation that are suitable for the illiterate rural population (where the majority of the population are dominated by elderly people, women and children) and identify public participation

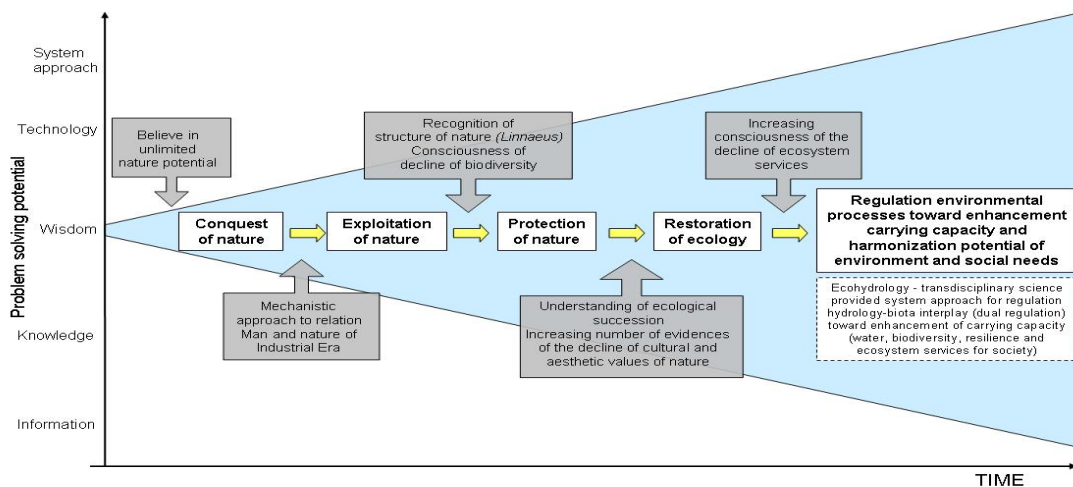
approaches that take into account the construct of the communities, which are strongly influenced by their ethnic, cultural and religious beliefs.

- Identify appropriate technology for agriculture, water and sanitation services that can be accepted, developed, operated and maintained by the local rural people, who often lack education/capacity and resources.
- Propose a new business model of infrastructure development and investment specifically for the rural poor that ensures the sustainable infrastructure development and operation (e.g. centralized subsidy model versus PPP model or any modification of them), and infrastructure development strategies that reconcile the conflicting domestic and agricultural water demand and efficient use and reuse of resources (e.g. Multiple Use Services -MUS- approach).
- Study a new institutional framework that can address the issues of rural area in an integrated approach and identify enabling institutional and governance structures (e.g. institution, decentralization and devolution, level of participation of NGOs' and community organization, policies and regulation, cost recovery and subsidies).

## THEME 5: ECOHYDROLOGY, ENGINEERING HARMONY FOR A SUSTAINABLE WORLD

### Background and challenges

In the face of increasing climate instability, demographic growth and human migrations, and the emergence of new geopolitical centres, which will affect the global economy (including food prices growth and intensified environmental impact), there is an urgent need to reverse degradation of water resources and stop further decline in biodiversity. Appreciation and optimization of ecosystem services for society along with enhancement of resilience of river basins to climatic and anthropogenic stress may greatly contribute to reach this goal.



Ecologyhydrology concept in the perspective of evolution of relations between man and environment (Zalewski, 2011)

In the Anthropocene, most of the global landscape, except deserts, high mountains and the boreal zone, has been converted into agricultural land with spots of highly modified urban areas. This over-engineering of urban and agricultural landscapes results in a reduction of biomass and organic matter, leading to a modification of the water cycle from the model situation where biological component stabilizes the heat budget and water dynamics at the intermediate disturbance level, to

a model where the water cycle accelerates and becomes more stochastic and unfavorable for biota and humanity (droughts and catastrophic floods). Additionally, these processes reduce carbon storage and nutrients transfer from mineral to organic forms, impacting the material cycle. To reverse those negative processes, a two-steps strategy has to be elaborated and implemented. The first proposed step should be based on von Weizsäcker's reduction of energy and matter use per GDP. The second proposed step is based on Ecohydrology theory to regulate hydrological and nutrients' cycles in "novel ecosystems" (agricultural and urban) towards the enhancement of carrying capacity of the global ecosystem. Carrying capacity enhancement is understood as the enhancement related to water resources, biodiversity, ecosystem services for societies and the resilience to increasing various forms of impact.

### ***Focal Area 5.1 - Hydrological dimension of a catchment – identification of potential threats and opportunities for a sustainable development***

#### **Overall Objectives**

The quantification and integration of hydrological and biological processes at the basin scale is based on the assumption that abiotic factors are of primary importance when become stable and predictable, then biotic interactions start to manifest themselves. The quantification covers the key elements of hydrological cycle (precipitation, evapotranspiration), patterns of hydrological pulses along the river continuum and monitoring of point and nonpoint source pollution, erosion, habitat degradation. The integration of information about hydrological cycle inputs and economical distribution provide a template to regulate processes toward sustainable water and ecosystem resources use. IHP will support research and capacity building initiatives aimed to improve the understanding of the inter-linkages of ecohydrological processes at the catchment scale with special emphasis on implementation at UNESCO EH demonstration sites.

#### **Specific Objectives**

- Increase knowledge base and further develop approaches to reduce threats, such as floods and droughts, by asserting the stochastic character of hydrological processes in catchments through harmonization of hydrotechnical infrastructure with the distribution and management of water retaining ecosystems.
- Support research and develop guidelines for the incorporation of an understanding of the past in River Basin Management Plans (e.g. paleohydrology, ecological succession patterns, spatial-temporal dynamics of human settlement).
- Promote model development to reduce hydro-peaking by integrate specific environmental science knowledge (e.g. hydrogeology, soil, groundwater, plant cover) and the floodplain characteristics.
- Develop catchment scale ecohydrological early warning system (by integrating molecular biomonitoring, hydrochemistry, geomorphology, land cover and use in the GIS framework).

### ***Focal Area 5.2 - Shaping of the catchment ecological structure for ecosystem potential enhancement – biological productivity and biodiversity.***

#### **Overall Objectives**

The concept emerges as an ecohydrological response based on the assumption that under intensive global changes it is not enough to protect ecosystems against increasing human population, energy and material consumption and increasing climate instability. It is necessary to regulate the 'novel (human modified) ecosystem' structure and processes (life support systems)

aimed at increasing the “carrying capacity” (water quality, restoration of biodiversity, ecosystem services for society, resilience of river ecosystem).

### **Specific Objectives**

- Improve the understanding on the role of different types of terrestrial and wetland ecosystems distributed in catchment on the water cycling processes.
- Support studies on the role of hydrodynamics and biological structure of the river basin in reduction of various types of pollution in demonstration sites.
- Develop methods to mitigate the impact of the catchment demographic and socioeconomic structure effect on water balance nutrients and pollutants in river fluxes.
- Potentiate and share knowledge on the integration of ecohydrological technologies with good agriculture/environmental practices for reduction of diffuse pollution from the landscape.

### ***Focal Area 5.3 - Ecohydrology system solution and ecological engineering for the enhancement of water and ecosystem resilience and ecosystem services.***

#### **Overall Objectives**

The use of ecosystem properties as a management tool is based on the first and the second principles of EH and related to ecological engineering. The implementation of social learning and communication methodology serves the harmonization of society’s priorities with expert knowledge and recent achievements of science, and jointly contributes to sustainable development based on enhanced ecosystem carrying capacity and ecosystem services.

Progressing global changes and increasing demand for more sustainable and efficient management focused on changing social needs and context, identification and evaluation, as well as functional incorporation of ecosystem services as integral element of water management and economics, sustainable water supply and demand models is a necessity. There is a need to change a perception of ecological systems in economic models from “compulsory costs” to “potential benefits”.

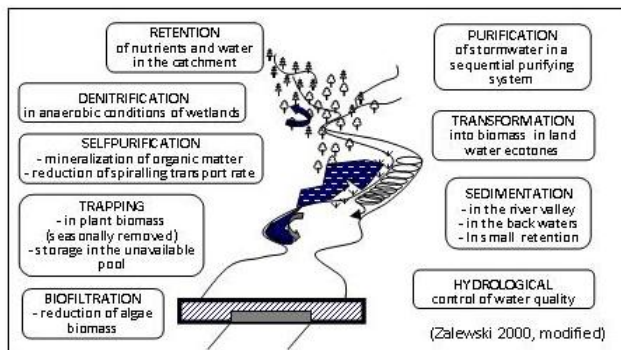
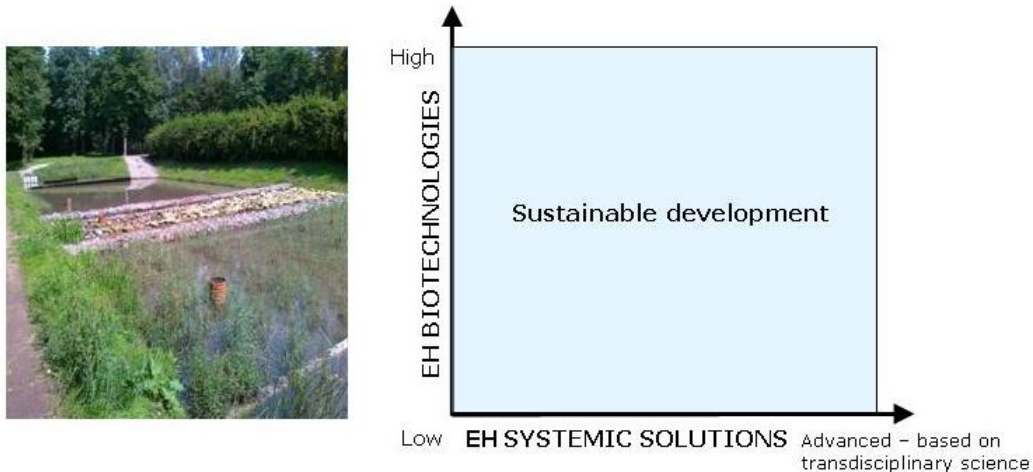
In both agricultural landscape and urban space, ecohydrological biotechnologies (based on “dual regulation”) have to be developed in order to increase water availability, food /bioenergy productivity, reduce diffuse pollutant emission, enhance biodiversity and serve human health and quality of life by development system approach toward regulation the complexity of interactions between the water cycle, ecosystems and societies.

#### **Specific Objectives**

- Identify good practices for implementing “dual regulation” for reduction of exceed nutrients and pollutants by the regulation of biota- hydrology interplay.
- Develop guidelines for the integration of various types of biological and hydrological regulations at the basin scale toward achieving synergy to improve water quality, biodiversity and freshwater resources, and optimize ecosystem services.
- Develop case studies relative to the harmonization of ecohydrological measures with existing or planned hydrotechnical solutions (dams, irrigation systems, sewage treatment plants, etc.) for a reduction of toxic algae blooms and adaptation to climate instability.

- Promote Ecohydrology low cost high-tech for IWRM and evaluation of ecosystem services in a catchment scale and development of tools for their efficient incorporation into Basin Management Plans.

Advanced technologies + Advanced systemic solutions  
 → Amplified potential for sustainable development



Conceptual model of synergy between ecohydrological biotechnologies and EH systemic solutions for building up river basin sustainability (adapted from Zalewski 2011)

**Focal Area 5.4 - Urban Ecohydrology – storm water purification and retention in the city landscape, potential for improvement of health and quality of life.**

**Overall Objectives**

Urban populations cause large demands on life-support resources and services, including water, which is one of the major causes of the world’s water crisis. The dynamic spatial expansion of cities is characterized by highly diverse patches of urban development and “novel ecosystems” impacts sustainability of cities. Therefore, the quality of life and human health are top priorities for the sustainable city development, thus the need for a new paradigm of holistic city management. In terms of the water cycle, one of the major impacts is the runoff management. But in urban areas, a change in the perception of storm water management can be accomplished through the application BMPs and more recently, ecohydrological biotechnologies for water purification and retention. Consideration for the enhancement of purified storm water retention in “green areas” in the city

spatial planning results as a friendly “blue-green city landscape” with reduced energy consumption, pollutants transfer and accumulation as well as improved human health, aesthetic and cultural values.

### **Specific Objectives**

- Identify and promote good practices for the reduction of urban storm water hydro-peaking by development of systems for infiltration, purification and retention of storm water.
- Develop guidelines for sustainable urban planning, based on combination of water sensitive urban design and ecohydrological biotechnologies for improving the quality of life and economics of urban systems and adaptation for global climate variations;
- Develop and strengthen frameworks and improve methodologies for cooperation in multi-stakeholder platforms and public participation for demand driven research and efficient application of the recent achievement of ecohydrology for IUWM.

### ***Focal Area 5.5 - Ecohydrological regulation for sustaining and restoring continental to coastal connectivity and ecosystem functioning***

#### **Overall Objectives**

Human pressure on coastal areas is undeniably extremely high. Eighty per cent of marine pollution comes from land-based sources and, in the developing world, more than 90% of sewage and 70% of industrial wastes are dumped untreated into surface waters where they pollute water supplies and coastal waters with harmful consequences to biodiversity, human health and coastal ecosystem services. By 2025 it is estimated that 75% of the world's population, or 6.3 billion people, will live in the coastal zone, naturally, this will increase the pressure on water resources and reduce their sustainability. In addition, global change is affecting coastal ecosystems both from land (e.g. changes in hydrologic cycles and precipitation patterns), and from the ocean (e.g. changes in sea level). Thus the urgent need to address these impacts and the interest in applying ecohydrological approaches to contribute to sustainable solutions.

#### **Specific Objectives**

- Share and improve regional ecohydrological solutions to the impact of global changes on hydrologic cycles and coastal ecosystems to address the increasing vulnerability of aquatic resources.
- Develop approaches and methods for dual management regulation - hydrology and biota -in river basin to improve water quality and biodiversity in coastal ecosystems.
- Improve the understanding of coastal ecosystems, as recipients of wastewater released from upstream sources, and develop case studies of how ecohydrology solutions may contribute to reduce the risk of several diseases occurring in estuarine zones.

## **THEME 6: WATER EDUCATION, KEY FOR WATER SECURITY**

### ***Background and Challenges***

To meet the challenges identified in the previous five themes, efforts should continue to be made to improve and update water education at all levels. In this context, water education must be interpreted in a broader sense than the teaching of hydrological sciences and related scientific disciplines. Water education within the eighth phase of IHP includes a multidisciplinary and



interdisciplinary approach aimed to advance scientific knowledge through the training of scientists, as well as to strengthen and enhance the water sector through the formation of water professionals and decision makers. Water education also entails working with mass and community media professionals to improve their capacities to communicate water issues accurately and effectively. In addition, the program includes community education strategies to promote community-wide water conservation, as well as skills in local co-management of water resources. Finally, actions to make water a significant component of the K-12 curriculum are considered an integral and important part of the water education agenda.

The major challenge that faces the implantation of the various focal areas identified within this theme is related to the need to mobilize adequate human resources to engage in educational and capacity building activities. Notwithstanding the work that started in the sixth phase of the IHP (2002-2007), and the substantial extension of IHP's action in the field of water education within the seventh phase (2008-2013), during the eighth phase efforts to attract and support scientists, professors, teachers and community mobilizers in the sector are to be multiplied to attain the objectives of the program. In this endeavor, the UNESCO-IHE Institute for Water Education and the network of UNESCO Category II Water Centres play an important role. Similarly, during phase VIII IHP is expected to continue to stimulate responsive actions through its partners across UNESCO and the UN System, as well as through its National Committees for the implementation the water education component.

### ***Focal Area 6.1 - Enhancing tertiary water education and professional capabilities in the water sector.***

#### **Overall Objectives**

This focal area addresses the enhancement of tertiary water education aimed at the formation of scientists to further develop water sciences, as well as to educate the new generations of water professionals, managers, and decision makers. To attain water security, the Member States face complex challenges linked to social, economic, climatic, and other factors of local, regional and global nature. Thus, the eighth phase of IHP contemplates the support and development of professional trainings and short courses for engineers, managers and policy makers in the water sector.

The IHP educational and research network constituted by UNESCO-IHE, the UNESCO Category II Water Centres, and the UNESCO Water-related Chairs are key institutions for the implementation of this focal area. Similarly, the network of universities, institutes and research facilities linked to the various programs of IHP are important partners to attain the goals of this focal area.

#### **Specific Objectives**

- Support the enhancement of tertiary water education capacities, particularly in developing countries.
- Promote and assist the development of interdisciplinary and multidisciplinary curricula and research initiatives linked to water-related programs in higher education and research institutions.
- Strengthen collaboration between UNESCO-IHE Institute for Water Education, the UNESCO Category II Water Centres and UNESCO water-related Chairs, other UN system agencies and programmes, and existing international water-related education programmes.
- Promote and support strategies and actions for continuous professional development of water scientists, engineers, managers and policy makers in the water sector.

- Develop interdisciplinary materials, such as guidelines, briefing papers, prototype professional development programmes and case studies connected with water education for water security, linked to the implementation of other themes and programmes of IHP.

### ***Focal Area 6.2 - Addressing vocational education and training of water technicians.***

#### **Overall Objectives**

During the past decades, the number of offers of water-related vocational programs to train water technicians has declined steadily. In addition, the rapid transformation and innovation of technologies requires the re-training of existing human resources at the technical level in the water-sector. This focal area aims to increase awareness on the need to address vocational education and training of technicians to sustain the water sector. Similarly, within UNESCO and in partnership with other UN system agencies and programmes, additional sustainable efforts are to be developed for maintaining and expanding the training of technicians in water-related fields (e.g. hydrometeorological monitoring, irrigation systems, sanitation, water supply systems, others).

An important action started as part of the seventh phase of IHP to be continued during the eighth phase of IHP consists of the survey and preparation of case studies with examples of leading practices in sustainable integrated water management for water technicians training. The implementation of this focal area contemplates the continuation of these actions and the analysis of these case studies and the support in the preparation of guidelines and Briefing Papers based on them.

#### **Specific Objectives**

- Support specific initiatives in developing Member States to sustain and improve water-related vocational education.
- Survey, prepare and analyze case studies of examples of leading practices in sustainable water management in water technicians training and support the preparation of guidelines and Briefing Papers based on them.
- Develop efforts within UNESCO and in partnership with other UN system agencies and programmes to maintain and expand the training of technicians in water-related fields.

### ***Focal Area 6.3 – Water education for children and youth.***

#### **Overall Objectives**

This focal area seeks to make water a significant component of the K-12 curriculum of primary, middle and high school education systems in Member States. Although formal education systems are the main focus of this focal area, other forms of initiatives will be considered, such as the development of water-related activities in children eco-clubs, sport clubs, explorers' groups. In the implementation of these activities, the programme contemplates working especially with the Education Sector of UNESCO, as well as with other partner organizations with a mission of enhancing water education in schools.

Important actions comprised in this focal area are related to the development of improved tools for the teaching of water issues in the K-12 curriculum. Similarly, the program addresses building and/or improving the capacity of teachers and informal educators to better understand water issues at the local, regional and global scales and commit to a water ethics. Teachers and informal educators, such as coaches, children's group leaders, among others, are not just important incubators of ideas and behaviors among children and young adults, but generally they are also respected within local communities. Thus the need to dedicate efforts towards the development of

their skills to communicate to their pupils and their communities and guide water related issues or actions.

### **Specific Objectives**

- Capacitate teachers and informal educators on water issues at the local, regional and global scales.
- Support and guide the development of improved tools for the teaching of water issues in the K-12 curriculum.
- Guide and provide technical support to national/regional demonstration projects and development of prototype materials at national/regional levels in selected Member States/regions.
- Provide technical assistance to the development of interdisciplinary support materials, such as guidelines, briefing papers, and case studies on leading practices in K-12 water education, and curriculum development on water resources, in coordination with other Sectors of UNESCO.

### ***Focal Area 6.4 – Promoting awareness of water issues through informal water education.***

#### **Overall Objectives**

This focal area aims to increase awareness on water issues among stakeholders, by working primarily with communities and mass media professionals. To attain food security, communities need to be involved, but their involvement needs to be based on appropriate knowledge and understanding of their watershed (natural, social, cultural conditions, as well as policies and regulations, economic trends and development opportunities, among other issues). Communities also have a more productive involvement in water management and conservation when they are organized. In this regard, the eighth phase of IHP contemplates the development of water education activities directed to communities. In this endeavor, the engagement of the IHP National Committees constitutes a needed and valuable asset.

In increasing awareness on water-related problems and issues, the mass media professionals can play an important role. However, limited efforts have been done to support mass media professional access unbiased knowledge and information on water issues. Thus the media reacts and reports mostly extreme water-related situations, at which state preventive measures or actions (relative to disasters, conflicts, contamination, loss of life and/or natural resources, others) cannot be entertained. The understanding of the importance of local, regional and global water issues among journalists, bloggers, producers of radio, television, film, multimedia and other mass and community media professionals and the subsequent continuous and adequate reporting is a unique and most efficient mechanism for increasing awareness among the general public on water resources.

#### **Specific objectives**

- Develop and promote community education strategies related to water issues (state of the resource, conservation, co-management, among other).
- Provide technical assistance to the development of interdisciplinary support materials, such as guidelines, briefing papers, and case studies on leading practices in water education for communities.

- Provide technical assistance to the development of interdisciplinary support materials, such as guidelines, briefing papers, and case studies on leading practices in water education for mass and community media professionals.
- Engage leading mass media resources in water issues awareness raising campaigns and programs.

### ***Focal Area 6.5 – Education for transboundary water cooperation and governance.***

#### **Overall Objectives**

This focal area will enable Member States to improve their institutions, strengthen professional capacities and develop regulations for the integrated and environmentally sound protection and management of transboundary water resources. The majority of the large basins and aquifers in the world are shared between two or more countries. Similarly, countries districts and/or provinces are limited by rivers or streams. The adequate management and conservation of water resources need to take place in a collaborative manner among countries through negotiations and the establishment of various forms of agreements. However, only a small amount of institutions around the world have specialized courses or programs on water negotiations for cooperation.

The objective of this focal area is to support the development of education initiatives aimed to support transboundary water cooperation and negotiations. UNESCO IHP established the long term PC-CP (From Potential Conflict to Cooperation Potential) program aimed to compile and develop wise practices and guidance tools concerning shared water resources management and negotiations. During the eight phase of IHP, actions to expand and increase the scope of transboundary water cooperation for food security will include the development of new capacity building tools, guidelines, curricula and case studies to support the Member States in their ongoing transboundary resources management and negotiations.

#### **Specific Objectives**

- Provide technical assistance for the development of interdisciplinary support materials, such as guidelines, briefing papers, and case studies on leading practices in education and capacity building for transboundary water cooperation.
- Improve Member States' cooperation and mutual understanding, strengthen capacities and develop agreements for the sustainable management of transboundary water through capacity building activities at all levels.
- Assist in the development of curricula and research on transboundary water cooperation in higher education institutions.

## **CHAPTER 6, PUTTING SCIENCE INTO ACTION**

One of the main objectives of IHP VIII is to put science into action, by promoting the process of transformation of information and experience into answering local and regional needs for tools to adapt IWRM to global changes and building competences to meet the challenges of today's global water challenges. To this end, it is essential to establish knowledge platforms where stakeholders, researchers, local institutions, policy makers, and education entities can exchange and share the information, communicate each other, and develop new ideas that would support policy making and decision taking. IWRM expands its holistic approach to water governance and management by balancing competing demands from diverse interests such as agriculture, industrial, domestic and environmental stakeholders within the context of climate change and population growth. The goal is

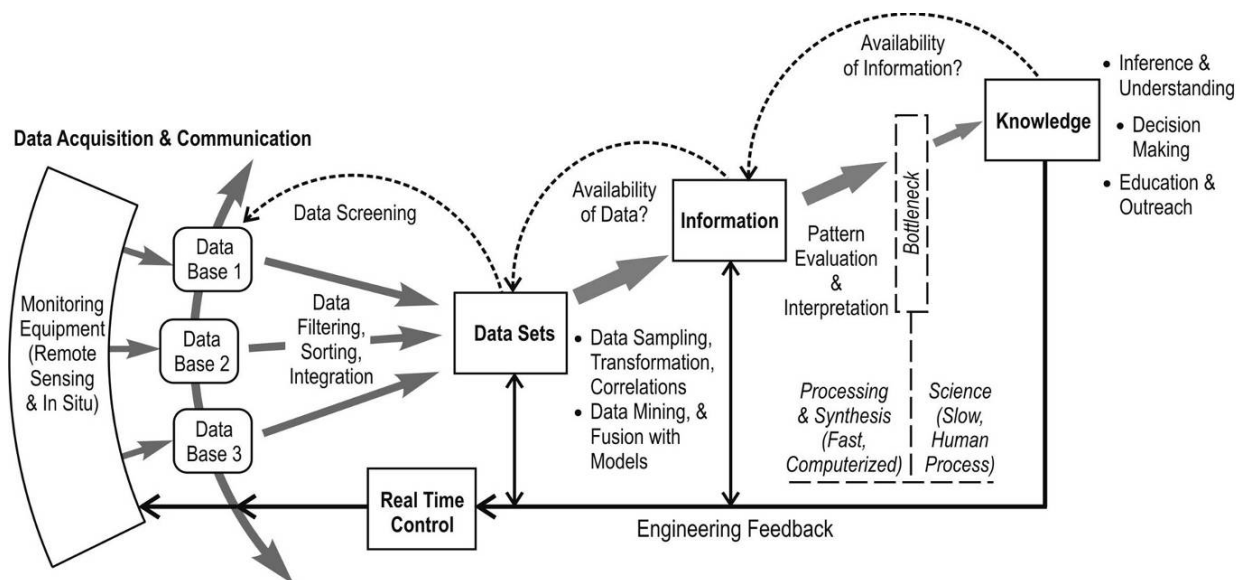
to help member states adapt new strategies that will make both their ecosystems and socioeconomic systems more resilient to climate variability and change and population growth. Adaptive Integrated Water Management (AIWM), a synthesis of IWRM and Adaptive Water Management (AWM), addresses uncertainty and complexity by increasing and sustaining the capacity to learn new information about socio-ecological processes and data while managing, and manage while learning. AIWM promotes a shift from management that emphasizes prediction and control to management as a learning approach. Learning is an iterative process, based on experience and insight. With AIWM, the results of implemented strategies are monitored, and insights shared. Those insights are applied to further test and improve both analytic methods and management approaches.

The communication between scientists and stakeholders is an important step toward development of community understanding and ownership of risk. Scientists have a responsibility to educate the community they serve regarding the risks for that community, and possible actions the community can take to reduce those risks. Likewise, stakeholders and policy makers have a responsibility to work closely with scientists in the social learning process.

Social learning has been identified as one of the “key processes” of successful water governance in watershed studies. Social learning as a water governance process offers scientists, stakeholders a framework for working together to:

1. Understand each other’s value systems for water decision-making
2. Develop trust
3. Define jointly the nature of the problem they are addressing
4. Engage in fact-finding
5. Develop and assess different strategies for addressing problems
6. Carry out a plan and assess its success in achieving their goals (Pahl-Wostl et al., 2008; Mostert et al., 2008).

Implementation of IWRM requires sound enabling technologies that make the conversion of data to knowledge a practical goal (refer to scheme on data-to-knowledge transformation).



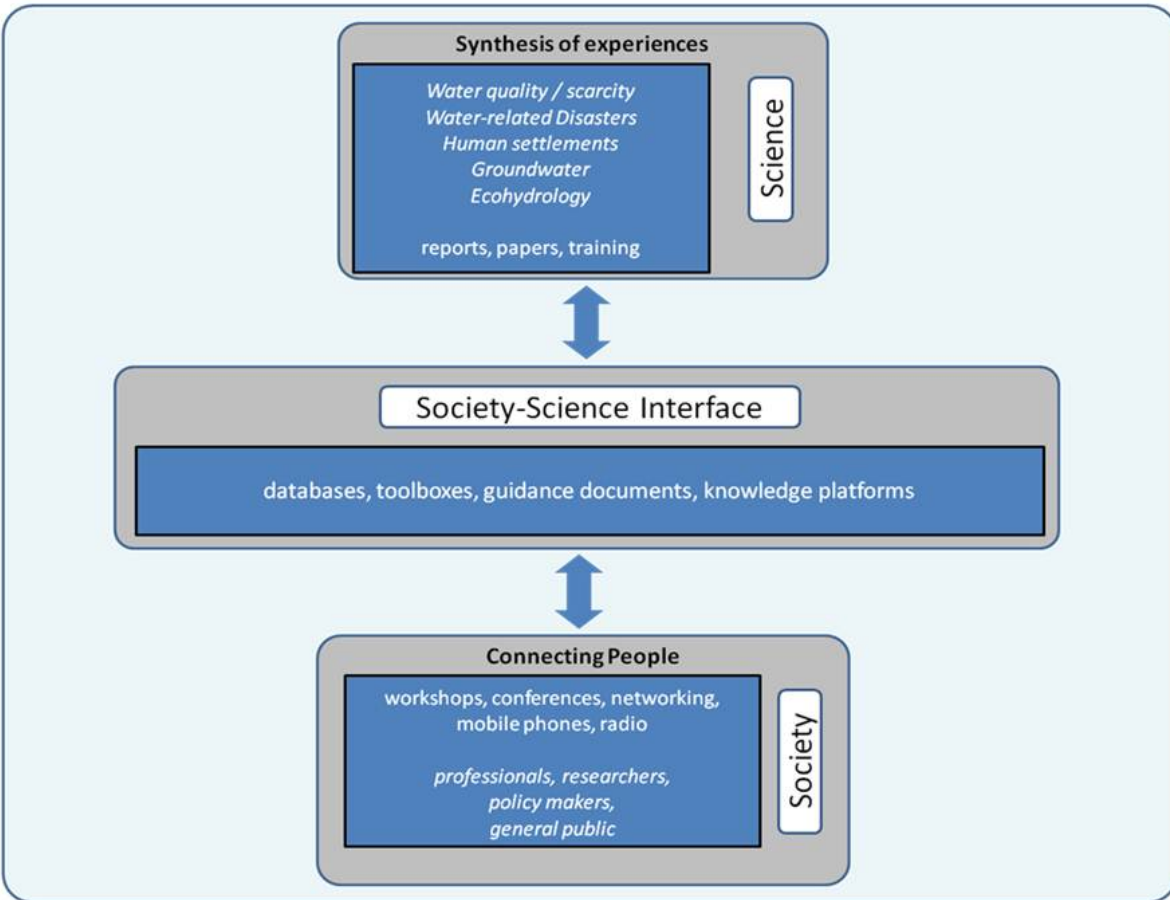
The data-to-knowledge transformation process taking place in the information system (adapted from Fletcher 2006)

The main tasks required to make science supporting policy making and decision-taking processes related to water issues at various levels (local, national and regional) are: 1. Integrate and disseminate (explicit and tacit) local knowledge, positive experiences, and recent research results related to adaptation and mitigation measures to cope with water-related issues, such as water scarcity, ecosystem deteriorations, and floods; 2. Identify and promote sustainable good practices for dealing with water related issues; 3. Transform and enhance local knowledge into adaptive capacity.

The illustration above schematically designates the hierarchy how raw data are abstracted and integrated into information, knowledge, and wisdom. The simple message is that single data will never be information, knowledge consists of plural information, and IWRM/AIWRM requires the synthesis of different kinds of knowledge. The illustration also highlights the importance of multi-disciplinary aggregation. Possibly, what is required in IHP is how to translate wisdom or knowledge on water into comprehensive expressions for citizens.

Knowledge management is an important aspect of the process of putting science into action. In fact, besides the availability of data, information and knowledge about aspects of water-related issues, the translation into feasible adaptation intervention strategies and actions with clear ownership, has not emerged yet at large scale. Scientific knowledge needs to be (firstly) shared and (secondly) applied to create a larger awareness of its impact and practical application. To this end, there is a need for activities to prepare the content for "sharing of knowledge": translation of the scientific text into messages that can be easily and effectively shared; organization of the sharing process (e.g. through platforms, exchange meetings). In fact, innovation is created when knowledge flows between scientists and disciplines, between various knowledge institutions, and between knowledge institutions and the public and private sectors. Essential components of the knowledge value chain consist not only of the creation of new knowledge, but also in disseminating knowledge by making it available and accessible and in applying and evaluating it. A key process here is (enabling) learning, which will support capacity development and increase "water literacy" among citizens. Enhanced water literacy should be required to digest and utilize the knowledge, particularly with various levels of uncertainties.

A simple schematization of the process of putting science into action can be seen as the interaction of "Science" and "Society". While the Science deals with the water related issues of the five themes of IHP VIII and produces reports, review papers, and provides training; the Society -which consists of professionals and researchers dealing with climate-related issues, policy makers and the general public- promotes the connection of people that is facilitated by the organization of workshops, conferences, and networking that use social learning. Such opportunities and connections are crucial to incubate the trust of citizens and policy makers on water professionals. Such trust indispensable for knowledge and information provided from water professionals to be effectively utilized in the society.



Simple schematization of the process of putting science into action

In such a scheme, the bulk of the process is represented by the intermediate level, i.e. the "Society-Science Interface", which will function as an interface between Society and Science by producing databases, toolboxes, guidance documents and knowledge platforms. One of the main goals is then the integration of indigenous local knowledge with the results of past and ongoing scientific activities.

In practice, hydrological sciences can contribute to society by monitoring and projecting changes, assessing impacts, examining possible adaptation options, and supporting decision making and actions at various levels. For example, hydrology can provide consistent information on the past and present states of the hydrological cycle: e.g. how much water is (and likely will be) available for human beings in a sustainable manner (e.g. "renewable" freshwater resources, ground water recharge rates)? How can structural and non-structural measures be used to support sustainability? Likewise, hydrological tools and models can provide reliable near-real time, mid-term, seasonal, and decadal predictions and/or projections of the changes in the hydrological cycle: e.g. how would frequencies of extreme hydrological events will change?. What will be the consequences of these changes on the society? And how can we reduce the risk of the anticipated water-related disasters?

In addition to a legacy spanning four decades, several of IHP's projects and programmes are already engaged in constructing complex data and knowledge platforms. For example, Water and Development Information for Arid Lands – A Global Network on Water and Development Information in Arid Lands (G-WADI) provides realtime remote sensing observation of precipitation for improved global forecasts. G-WADI regional networks are also engaged in the process of constructing other important data sets such as the Asian G-WADI network, which was established in March 2005, and is currently working on establishing a comprehensive global sediment data set in cooperation with ISladditional networks in Africa, the Arab region, and in Latin America and the Caribbean being established with the goal of creating knowledge exchange platforms. Over the years, the FRIEND programme developed a substantive knowledge base and built a wide network of cooperation in data exchange even in regions where such was a difficult task to start with. Similarly, the recently launched International Drought Initiative is already engaged in facilitating access to global forecasts of drought conditions and in supporting, together with the African G-WADI the efforts to develop a network of centres in Africa that will produce regional drought forecasts, assessments, and policy relevant information. The inventory of shared groundwater aquifers, produced through the WHYMAP programme in cooperation with IHP ISARM initiative is but one more example of such complex data sets and knowledge bases. It is natural that the next step would be for IHP to build on emerging platforms and networks that aim to facilitate integration of heterogeneous platforms and enhanced connectivity through the growing cyber-infrastructure. For example, in the U.S., the National Science Foundation (NSF) communities, namely the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) and the WATER and Environmental Research Systems Network (WATERS Network), have promoted alliances among U.S. universities to develop and implement cyber infrastructure-based environmental observatories for watersheds. These initiatives focus on distributed data collection, management, and operation of a network of observing stations or interacting scientific activities across time and space. Some of these activities have been explicitly organized as observatories (e.g., NEON, NVO, GEON) while others are focused on core technologies critical to observatories, including high performance computing (e.g., TeraGrid, OptIPuter), data federation (e.g., BIRN), or informatics (e.g., SEEK).

Similarly, The International TIGER initiative of the European Space Agency has been a long-term partner in IHP capacity building efforts in the area of advanced remote sensing technologies and data sets. TIGER Net provides a fully integrated water information system, which enables continuous retrieval of different hydro-geological variables and biophysical parameters relevant to the water-energy cycle such as water quantity and quality, vegetation, land use, land cover, topography, floods and droughts. TIGER Net performs thought analysis of the user requirements in terms of geo-information products to enhance current Water Information Systems and improve existing practices in Integrated Water Resource Management and develops and demonstrates in selected pilot countries/regions the integration of advance Earth Observation applications within existing or under development national or regional Water Information Systems to match user needs and overcome problems faced in the collection, analysis and use of water related geo-information. The European Drought Centre is a virtual knowledge centre coordinates drought related activities in Europe to better mitigate the environmental, social and economic impact of droughts. The EDC promotes collaboration and capacity building between scientists and the user community and thereby increase preparedness and resilience of society to drought



## ANNEX 1. IHP PROGRAMMES

As a science and education programme at the global level, IHP covers a wide spectrum of programmes and initiatives. All IHP-related activities are endorsed, recommended and coordinated through the IHP Intergovernmental Council.

IHP's two cross-cutting programmes, FRIEND and HELP, interact with all IHP themes through their operational concepts. IHP's associated programmes cover projects and activities that contribute to the development and implementation of IHP themes, and are often interlinked with joint and interagency programme components.

### **FRIEND (Flow Regimes from International Experimental and Network Data)**

An international research programme that helps to set up regional networks for analyzing hydrological data through the exchange of data, knowledge and techniques at the regional level.

### **GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change)**

A UNESCO-led project seeking to improve our understanding of how groundwater interacts within the global water cycle, how it supports human activity and ecosystems, and how it responds to the complex dual pressures of human activity and climate change.

### **G-WADI (Global Network on Water and Development Information in Arid Lands)**

A global network on water resources management in arid and semi-arid zones whose primary aim is to build an effective global community to promote international and regional cooperation in the arid and semiarid areas.

### **HELP (Hydrology for the Environment, Life and Policy)**

A new approach to integrated catchment management by building a framework for water law and policy experts, water resource managers and water scientists to work together on water-related problems.

### **IFI (International Flood Initiative)**

An interagency initiative promoting an integrated approach to flood management which takes advantage of the benefits of floods and the use of flood plains, while reducing social, environmental and economic risks. Partners: the World Meteorological Organization (WMO), the United Nations University (UNU), the International Association of Hydrological Sciences (IAHS) and the International Strategy for Disaster Reduction (ISDR).

### **ISARM (Internationally Shared Aquifer Resources Management)**

An initiative to set up a network of specialists and experts to compile a world inventory of transboundary aquifers and to develop wise practices and guidance tools concerning shared groundwater resources management.

### **ISI (International Sediment Initiative)**

An initiative to assess erosion and sediment transport to marine, lake or reservoir environments aimed at the creation of a holistic approach for the remediation and conservation of surface waters, closely linking science with policy and management needs.

**JIIHP (Joint International Isotope Hydrology Programme)**

A programme facilitating the integration of isotopes in hydrological practices through the development of tools, inclusion of isotope hydrology in university curricula and support to programmes in water resources using isotope techniques.

**PCCP (From Potential Conflict to Cooperation Potential)**

A project facilitating multi-level and interdisciplinary dialogues in order to foster peace, cooperation and development related to the management of shared water resources.

**UWMP (Urban Water Management Programme)**

A programme that generates approaches, tools and guidelines which will allow cities to improve their knowledge, as well as analysis of the urban water situation to draw up more effective urban water management strategies.

**WHYMAP (World Hydrogeological Map)**

An initiative to collect, collate and visualize hydrogeological information at the global scale to convey groundwater-related information in a way appropriate for global discussion on water issues.

IDI (International Drought Initiative)

## **ANNEX 2. ACRONYMS**

AIWM - Adaptive Integrated Water Management

AMCOW – [note: on page 4, please use correct denomination: African Ministers' Council on Water]

AWM – Adaptive Water Management

BIRN – Biomedical Informatics Research Network

CUAHSI - Consortium of Universities for the Advancement of Hydrologic Science, Inc.

EDCS - Environmental Data Coding Specification

EH – Ecohydrology

ESA Tiger Net – European Space Agency Tiger Initiative

FRIEND - Flow Regimes from International Experimental and Network Data

G-WADI – Global Network on Water and Development Information in Arid Lands

GDP – Gross Domestic Product

GEF – Global Environment Facility

GEMS – Global Environmental Monitoring System

GIS – Geographic Information System

GRAPHIC - Groundwater Resources Assessment under the Pressures of Humanity and Climate Change

GWES - Groundwater for Emergency Situations

GWP - Global Water Partnership

HELP – Hydrology for the Environment, Life and Policy

IAH – International Association of Hydrogeologists

IDI – International Drought Initiative

IFI - International Flood Initiative

IHP - International Hydrological Programme

IGRAC - International Groundwater Resources Assessment Centre

IPCC - Intergovernmental Panel on Climate Change

ISARM - Internationally Shared Aquifer Resources Management

ISI - International Sediment Initiative

IUWM – Integrated Urban Water Management

IWRM – Integrated Water Resources Management

LID - Low Impact Development

MAR – Managed Aquifer Recharge

MDGs - Millennium Development Goals

NEON - National Ecological Observatory Network

NGO – Non-Governmental Organization

NSF – National Science Foundation

NTSs – Natural Treatment Systems

NVO - National Virtual Observatory

OptIPuter - Optical networking, Internet Protocol

PhACs - Adsorption of Pharmaceutically Active Compounds

PUB – Predictions in Ungauged Basins

PC-CP – From Potential Conflict to Co-operation Potential

SEEK: Sharing Environmental Education Knowledge

SES – Socio-ecological systems

SIDS – Small Island Developing States

SRTM - Shuttle Radar Topography Mission

SUDS - small-scale decentralized urban drainage systems

SWITCH – Sustainable Water management Improves Tomorrow’s Cities’ Health (also known as SWITCH Project)

TeraGrid ([www.teragrid.org/](http://www.teragrid.org/) ) National Science Foundation's effort to build and deploy the world's largest distributed infrastructure for open scientific research

UNDAF - United Nations Development Assistance Framework

UNDP - United Nations Development Programme

UNGA – United Nations General Assembly

UNESCO - United Nations Educational, Scientific and Cultural Organization

UNICEF - United Nations Children's Fund

UNICL – United Nations International Low Commission

UNU – United Nations University

UNWWDR - United Nations World Water Development Report

WHYMAP – Worldwide Hydrological Mapping Assessment Programme

WHO – World Health Organization

WWAP – UN World Water Assessment Programme

WWC – World Water Council

WWF– World Water Forum