



United Nations
Educational, Scientific and
Cultural Organization



International
Hydrological Programme

THE IMPACT OF **GLOBAL CHANGE** ON WATER RESOURCES:

The Response of UNESCO's
International Hydrological Programme



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This brochure provides an overview of the likely effects of global change (population growth, climate change, urbanization, expansion of infrastructure, migration, land conversion and pollution) on water resources and the International Hydrology Programme's response to these challenges. It reflects information about the water-related impacts of climate change as documented in reports of the Intergovernmental Panel on Climate Change (IPCC), the most comprehensive scientific assessment of this issue to date.



THE CONTEXT

WATER IS NECESSARY FOR LIFE. IT IS THE KEY RESOURCE FOR HUMAN HEALTH, PROSPERITY AND SECURITY.

Beyond water's functions in the hydrological cycle, it has social, economic and environmental values, and is essential for sustainable development.

Unprecedented population growth, a changing climate, rapid urbanization, expansion of infrastructure, migration, land conversion and pollution translate into changes in the fluxes, pathways and stores of water – from rapidly melting glaciers to the decline of groundwater due to overexploitation.

Population density and per capita resource use have increased dramatically over the past century, and watersheds, aquifers and the associated ecosystems have undergone significant modifications that affect the vitality, quality and availability of the resource. Current United Nations predictions estimate that the world population will reach 9 billion people in 2050. This exponential growth in population – a major driver of energy consumption and anthropogenic climate change – is also the key driver behind hydrologic change and its impacts.

Rapid urban growth strains the capacity of governments to provide basic services such as water and sewerage. More than half of the world's population currently lives in cities; urban dwellers will account for 70 percent of humanity in 2050.

Arid and semi-arid areas face the greatest pressure to deliver and manage freshwater resources globally. By the mid-1990s, some 40 percent of the world's population were suffering water shortages. In less than 25 years, two-thirds of the world's population will be living in water-stressed countries.

More than half of the world's population relies on the freshwater that accumulates in mountainous regions. These areas are under pressure from deforestation, agriculture and tourism, all of which are placing unsustainable demands on water.

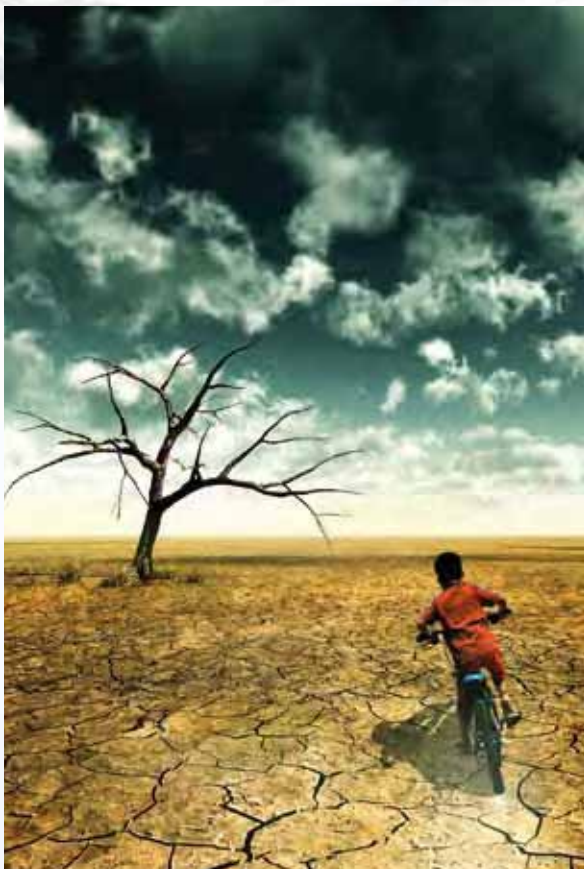
The quality and quantity of freshwater from rivers, lakes, groundwater, soil moisture, and ice is under stress around the world. Water pollution is a serious global problem which impacts the health of freshwater systems and the people who rely on them for water.

Many major rivers no longer consistently make it to the ocean; hundreds of meters of decline in fossil groundwater sources are now endemic in some of the largest and most productive aquifers in the world; and pollution has dramatically impacted the aquatic habitat in many of the world's prized water bodies.

UNESCO'S INTERGOVERNMENTAL SCIENTIFIC PROGRAMME IN HYDROLOGY AND WATER RESOURCES

These local and regional changes, coupled with global climate change, pose a momentous challenge to humanity and ecosystems. Considering the finite nature of water, its deteriorating quality and our increasing demand for it, the need to protect and manage freshwater resources is crucial.

Since these changes are a global problem, a response to its impacts must also be international. No single institution or country can face these challenges alone, but UNESCO provides a unique cross-disciplinary forum for addressing these issues. It can foster the necessary international cooperation to bring all players together, whether they are governments, research



DATA AVAILABILITY AND SHARING

Improving both data sources as well as access to them is critical for the assessment, prediction and adaptation of global change. Benchmark hydro-meteorological data sets need to be made available for all aspects of change prediction, assessment and modelling. Yet data are sparse in the developing world and global hydro-geological data sets to support assessment and prediction of change in groundwater systems are virtually non-existent. Even where such data have been collected, they are rarely shared across ministries or institutions.

Several IHP programs and their partners already work on various aspects of data collection. These efforts could be further leveraged to initiate a coordinated approach to assess and predict hydrologic change – locally, regionally, nationally and globally – as part of an initiative to adaptively manage hydrologic risk and mitigate the emerging global water crisis.

Global multidisciplinary data sets that are sufficiently refined and long enough to allow systematic change analysis and its attribution are needed. They may not exist in many places, and alternate ways to predict and assess changes based on classification and typology development may be needed. New monitoring networks that can aid this classification process and constrain predictions and early warning of change would also be useful.

institutions, universities, UN agencies, NGOs, and national or international organizations.

The mission of the International Hydrological Programme (IHP) is to strengthen the scientific understanding of these impacts on water systems and to link scientific conclusions to policies for promoting sustainable management of water resources.

KEY GLOBAL CHANGE DRIVERS

GLOBAL CHANGE INVOLVES MORE THAN CLIMATE CHANGE. THE MAJOR DRIVERS OF GLOBAL CHANGE ARE POPULATION GROWTH, CLIMATE CHANGE, URBANIZATION, EXPANSION OF INFRASTRUCTURE, MIGRATION, LAND CONVERSION AND POLLUTION.

Water resources are significantly affected by global change. There are few areas of the world where river basins and aquifer systems are not impacted by the numerous other drivers related to human activity.

Important increases in urbanization are modifying areas near river courses and low lying coastal areas. Seventy percent of water is currently withdrawn for agricultural use. Intensification of agriculture is contributing to deforestation and desertification. Increased water use associated with agriculture and urbanization is leading to changes in storage infrastructure, high rates of groundwater use, and new conveyance networks. Collectively these changes lead to cumulative effects on water quality.

Climate change increases the uncertainty associated with the future availability and variability of freshwater resources, and may even lead to permanent desertification of certain regions of the world. The impacts of floods and droughts in many areas will

have to be managed more frequently than in the 20th century. These are exacerbating factors on top of the direct human-induced changes in the local terrestrial hydrologic cycle that are further translated into large cumulative effects as one moves from watersheds to river basins, and as one looks at the chronic and progressive depletion and pollution of surface and groundwater reservoirs.

Climate exigencies such as drought can lead to increased groundwater pumping or investment in new surface storage, which have long-term hydrologic effects. Increased uncertainty with regards to climatic outcomes and hence to the renewable freshwater supply can change the investment and use directions in regional water resources. Increased flood magnitude and frequency can translate into changes in sediment fluxes and the mobility of biological and chemical pollutants, as well as in investment in flood control works which, in turn, impact future sediment and water residence times.





There is a need to learn more about these global drivers of water use in conjunction with local water availability. Agriculture is a dominant global water consumer and virtual water transactions through the global agricultural trade are now a significant part of this water budget. The policy and the physical dimensions of this component of the water budget and its interaction with local and regional water availability need to be better understood. Energy availability and use for water production, as well as water constraints on energy production enter the water access and availability equation as determined by local energy and water subsidy policies.

We also need to better understand and further develop the vulnerability, resilience and adaptability of different water management institutions and structures in stimulating and dealing with a changing environment. Water resources infrastructure development and management has historically required significant public funding by national and international agents. More research on the interaction between local and global actors in determining the future vulnerability and resilience of these systems and their local management to adapt to changing conditions is necessary.

Many regions already face crises related to the cumulative effects of global change drivers, especially on water resources. The consequence of these effects is aquifer depletion and water pollution, increased water stress and impacts of climate extremes, food security, access to safe drinking water, as well as socio-economic and ecological vulnerability. Yet change detection and attribution are difficult due to the absence of accessible data on the causative factors and outcomes.

Formal risk assessment and scenario analysis procedures can help us identify the vulnerabilities to change, predict risk, assess the significance of the risk relative to the impact and uncertainties, and to propose and test adaptation strategies. Both climate and other factors need to be considered in assessing sensitivity to change. Such a framework would be useful to focus and guide global change research.

Specific issues and tools in the application settings related to inter-basin transfer or upstream-downstream competition for water should be formulated in this context. There are prospects for modelling and predicting floods and droughts at different time scales using a variety of methods. Such events have huge global economic and social impacts, and a classification and prediction capacity is a prerequisite for adaptive management.

WATER DEPENDENCIES: SYSTEMS UNDER STRESS AND SOCIETAL RESPONSES

Adapting to the impacts of global changes on river basins and aquifer systems

The influences of global changes on water are playing a significant role in IHP's seventh phase (2008-2013), entitled "Water Dependencies: Systems under Stress and Societal Responses".



Several research activities on assessment and adaptation to global change impacts on freshwater resources have been identified:

- The development of monitoring networks and databases for change analysis
- Methods for change detection, attribution and prediction
- Prediction of changes in and vulnerability of groundwater, floods, low flows and droughts
- Prediction of groundwater quality degradation and restoration
- Assessment of snow, ice and glacier mass balances
- Assessment of the impact on sediment transport
- Integrated water management for adaptation to global change risk
- Policy-related interventions for adaptation

IHP's two cross-cutting programmes, FRIEND Water and HELP, interact with all IHP themes through their operational concepts.

FRIEND WATER: FLOW REGIMES FROM INTERNATIONAL EXPERIMENTAL AND NETWORK DATA



FRIEND Water is 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.

FRIEND Water's scientific research focuses on the understanding of the complex nature of hydrological variability in space and time in different hydro-climatic and hydro-geological environments (temperate climates, extreme elevation, monsoonal regimes, snow and ice regimes, hard rock and unconsolidated river basins, and data-sparse regions). The program deals with environmental change, including climate change and land-use changes and their impacts on extreme events such as floods and droughts, water resources, livelihoods, economic development and health.

HELP: HYDROLOGY FOR THE ENVIRONMENT, LIFE AND POLICY



HELP is a cross-cutting and transdisciplinary initiative that is creating a new approach to integrated catchment management through the creation of a framework for water law and policy experts, water resource managers and water scientists to work together on water-related problems.

An important research question within HELP basins is how knowledge, understanding, and predictive modelling of the influence of global climate variability and change on hydrological variables and remotely sensed data can be used to improve the management and design of water resource, agro-hydrological and eco-hydrological systems.

THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES

THE IMPACT OF GLOBAL CLIMATE CHANGE ON WATER RESOURCES IS A PRIMARY CONCERN FOR LOCAL AND GLOBAL WATER RESOURCES MANAGEMENT.

The impacts of climate change – including changes in temperature, precipitation and sea level rise – are expected to have varying consequences for the availability of freshwater around the world. Climate change impacts the hydrological cycle and thus impacts the management of freshwater resources. Changes in river runoff, for example, will affect the yields of rivers and reservoirs, navigation, and have an impact on the energy sector, finally affecting the recharging of groundwater. An increase in the rate of evaporation will also affect water supply and contribute to the salinization of irrigated agricultural lands.

Climate change impacts at all levels are projected to become increasingly strong in the decades following 2025. It is at the national level that the most important decisions need to be made, and adaptation strategies developed. Higher temperatures and decreased precipitation may lead to decreased water supplies and increased water demand. This may cause deterioration in the quality of freshwater bodies, putting further strain on the already fragile balance between supply and demand in many countries. Even where precipitation might increase, there is no guarantee that it would occur at the time of year when it would be useful. There is also a likelihood of increased flooding.



EXTREMES: FLOODS AND DROUGHTS

In recent years many countries around the world experienced devastating floods resulting in many deaths and damage to infrastructure. The IPCC predicts that by 2080, millions more people will experience flooding every year due to sea level rise. Decreased land precipitation and increased temperatures are important factors which have contributed to more regions experiencing droughts. Droughts aggravate food security and lead to an increase in food prices which, in turn, puts further stress on the most vulnerable in society.

FRIEND WATER AND HYDRO-HAZARDS

Through its eight regional groups, FRIEND Water focuses on the assessment of the impact of global change drivers on flow regimes with a strong emphasis on hydro-hazards such as floods and droughts, and has developed several flood-related tools such as early flood forecasting systems and design flood methods.

Research results demonstrate the difficulty of distinguishing between natural variability and human influences that reduce or enhance low flows and drought. Without detailed information, it is therefore impossible to attribute changes in drought characteristics to certain causes. For example, in many regions the impacts of land use change, urbanization or abstraction for irrigation override the effect of climate change. A promising approach is an integrated observation-driven approach that confirms the dependencies with modelling.

The research focus of the regional groups is on areas which are likely to experience change in the near future. One focus, for example, is to understand the underlying processes of major recent events and address scaling issues.

WATCH: THE IMPACT OF CLIMATE CHANGE ON DROUGHTS

The European (EURO) FRIEND Water group is researching the impact of climate change on droughts through the "Global Change and Ecosystems" project, as part of the EC-funded project WATCH (Water and Global Change). A study on trends in observed low flow and stream flow drought has been conducted and indicates the difficulty in detecting the climate signal in the hydrological time series. The research shows that the frequency and severity of droughts in Europe depend on the hydro-geological conditions (storage capacity) of the basins, the time period selected and the selection of the drought index itself.



IFI: INTERNATIONAL FLOOD INITIATIVE

The International Flood Initiative (IFI) promotes a holistic approach to flood management, and is a collaborative effort of WMO, UNESCO, IAHS, UNU and ISDR. The secretariat is based in the International Centre for Water Hazard and Risk Management (ICHARM) in Tsukuba, Japan. The impact of climate change on floods is an important issue within the initiative. IHP recently launched a new book series entitled "Flood Management in a Changing Climate" as a contribution to the International Flood Initiative (IFI). The books will focus on extreme precipitation and climate change, hydrologic modelling of floods,

flood inundation modelling and flood risk management providing sound knowledge to the theory of flood disaster management and practice under the current climate change conditions. Best practices from around the world and state of the art knowledge will be presented together with a set of computational tools for practical applications.

IHP compiled a list of major floods from around the world from 1860-2008 with a focus on their magnitude, meteorological causes and socio-economic impacts, in cooperation with IAHS. These findings were a contribution to the third World Water Development Report (WWDR).

ARID AND SEMI-ARID ENVIRONMENTS

Arid and semi-arid areas globally face the greatest pressures to deliver and manage freshwater resources. These areas are particularly vulnerable to climate variability or climate change, with consequences that may have very serious social and environmental effects.

Accurately assessing and managing available and renewable water resources is more difficult in semi-arid regions, compared with water-rich countries, since the science base is limited, data are scarce and the humid zone experience is inappropriate. Moreover, many arid regions are the focus of potential conflicts over water scarcity, making it necessary to develop strategies to support peace and security. Improved scientific understanding, cooperation and data sharing all provide ways of bettering water management and of supporting conflict resolution.



been to build an effective global community through the integration of existing material from networks, centers, organizations and individuals who are members of G-WADI. The International Center for Integrated Water Resource Management (ICIWaRM) in Virginia, USA serves as the host for the technical secretariat of the programme, which has regional networks in Asia, Africa, Latin America and the Arab region.

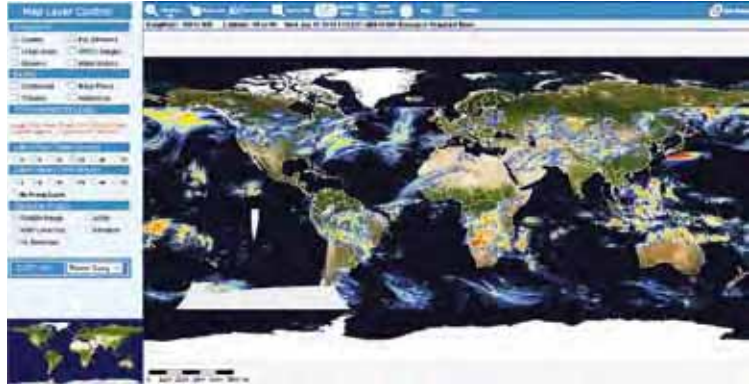
G-WADI: GLOBAL NETWORK ON WATER AND DEVELOPMENT INFORMATION IN ARID LANDS

G-WADI aims to strengthen the global capacity needed to manage the water resources of arid and semi-arid areas. The programme's primary aim has

Through workshops the programme brings together international experts, scientists, policymakers, researchers and stakeholders to discuss key research topics related to climate change impacts, risk assessment and management of water resources of arid and semi-arid regions.

G-WADI Geo-server Development:

Since the inception of the G-WADI program, the Center for Hydrometeorology and Remote Sensing (CHRS), University of California, Irvine has been collaborating with IHP on the development of tools to provide access to global satellite estimates of precipitation at high spatial and temporal resolutions that are relevant to the monitoring of precipitation input, especially important in transboundary basins and aquifers in areas where ground observation networks are lacking. The website contains applications and tools for water resource managers that can improve flood forecasting and warning, as well as drought monitoring.



popularity, particularly in the developing world. It will strengthen the capacity to manage water resources around the globe by allowing operational hydrologists and water resources managers access to satellite-based global precipitation estimates within one to two hours of the actual acquisition of the global infrared imagery.

COLD ENVIRONMENTS: SNOW, GLACIERS AND PERMAFROST

Glaciers are an intrinsic element of the culture, landscape, and environment in high mountain regions, and are key indicators and unique demonstrations of global warming and climate change. With rising global temperatures, glaciers are experiencing a rapid decline in mass. Changes in mountain glaciers will have significant effects on livelihoods and ecology.



Glaciers represent a unique source of freshwater for agricultural, industrial and domestic use, as well as an important economic component of tourism and hydroelectric power production. It is therefore critical to assess and monitor all aspects of water resources in the highly important headwaters of rivers and observe

changes in and consequent impacts on river regimes of the melting of snow, glacier ice and permafrost. The need for a worldwide inventory of existing perennial ice and snow masses was first considered during the International Hydrological Decade declared by UNESCO for the period of 1965-1974.

Current and proposed IHP activities related to glaciers, snow and permafrost include:

- Review ongoing studies of the hydrological impacts of glaciers, snow and permafrost, formulate further research needs;
- Develop a regional network of benchmark basins based on existing research and monitoring sites to provide an effective long-term capability to assess and monitor changes in snow, glacier and permafrost conditions;
- Improve coordination and exchange of information between the different organizations involved in monitoring glaciers in the region;
- Improve capacity of the scientists and institutions of the region to apply advanced methods and technologies (including use of satellite images) in assessing the status of snow and glaciers, and the impact of climate variability on them; and
- Raise awareness of policy-makers at the national level on the predictions and risks related to the melting of glaciers.

WATER QUALITY

The impact of climate change on water quality is likely to be considerable. The projected reductions in precipitation and runoff will lead to a decrease in both the quantity and quality of water supply.



Droughts deteriorate water quality since less water is available for the dilution of wastewater. Higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This promotes algal blooms and increases bacterial and fungal content, and, in turn, impacts ecosystems, human health, and the reliability and operating costs of water systems. Rising temperatures are likely to lower water quality in lakes through increased thermal stability and altered mixing patterns, resulting in reduced oxygen concentrations and an increased release of phosphorus from sediments.

More intense rainfall is expected to lead to a deterioration of water quality since it enhances the transport of pathogens and other dissolved pollutants (such as pesticides) to surface water and groundwater. It also results in increased erosion, which in turn leads to the mobilization of adsorbed pollutants such as phosphorus and heavy metals. More frequent heavy rainfall will overload the capacity of sewer systems, and water and wastewater treatment plants more often. In areas with overall decreased runoff such as in semi-arid areas, water quality deterioration will be even worse.

IHP is addressing water quality issues through a program aimed at protecting water quality. The impact of climate change on water quality is one of the key areas where specific activities, projects and case

studies on related topics are being developed. In addition, IHP is working on policy recommendations for mitigation and adaptation measures.

The activities will focus on the following strategies:

- Minimizing pollution load in rivers and surface water bodies during extreme weather events such as floods and droughts;
- Developing sustainable approaches to sanitation and wastewater management in order to prevent the increased sewage contamination of surface and groundwaters and transmission of water- and vector-borne diseases during flood events;
- Developing strategies for augmenting and maintaining the resilience capacity of the natural aquatic environment to cope with pollution.

EROSION AND SEDIMENTATION

Every year human lives are lost to erosion, landslides and debris flows. The negative impacts of erosion and sedimentation are further exacerbated by global changes brought on by a rapidly growing population and increased vulnerability to severe climatic conditions, which increase soil erosion.

Across the world, erosion, transport and sedimentation processes have significant social, economic and environmental impacts. More than fifty percent of the original storage capacity of the world's reservoirs is likely to be lost within the next thirty years due to sedimentation. Because of their close links to land cover, land use and the hydrology of a river basin, erosion and sediment transport processes are sensitive to changes in climate and land cover as well as to a wide range of human activities. These include forest cutting and land clearance, the expansion of agriculture, land use change and conservation practices, mineral extraction, urbanization and infrastructural development, sand mining, dam and reservoir construction, and programmes for soil conservation and sediment control. Soil erosion rates and sediment loads transported by the world's rivers provide an important and sensitive indicator of changes in the operation of the earth system. Sediment management is therefore an important component of sustainable water resources management.

Direct human activity is generally a stronger change agent on soil erosion and its hydrologic impacts than climate, although better understanding is needed as to how climate and land cover change lead to erosive and erodibility interactions.



ISI: INTERNATIONAL SEDIMENT INITIATIVE



ISI advances sustainable sediment management at the global scale in an effort to contribute to sustainable water resources management. The technical secretariat for the programme is based in the International Research and Training Center on Erosion and Sedimentation (IRTCES) in Beijing, China. The work includes an information system, a global evaluation of sediment transport (the GEST project), an assembly of case studies of sediment problems and sediment management for river basins in different environments, a review of erosion and sedimentation research, and an initiative to promote education and capacity building in the sediment field.

The theme of global change and its impact on erosion and sediment dynamics is central to all of these aspects since it is now clear that change is a key feature of those dynamics and such change is in turn a key driver of sediment-related problems and has a fundamental influence on sustainable river basin management. ISI plays an important role in highlighting the wider context of global change and the importance of such change to erosion.

“The Impact of Global Change on Erosion and Sediment Transport by Rivers: Current Progress and Future Challenges” is a contribution to the WWDR side publications intended to provide scientific information on subjects covered in the WWDR.



URBAN SETTLEMENTS

Urban water and sanitation services are directly affected by climate change. Changes in rainfall patterns, their seasonality and spatial distribution will influence the quantity and quality of water resources, and will impact both surface water and groundwater.

The projected increase in intensity and frequency of extreme precipitation events is likely to put sewerage networks under additional pressure. The current hydraulic capacity of parts of the networks will more often be exceeded. A result may be more frequent localized flooding and sewer overflows, which might in turn negatively affect the water quality of rivers.

UWMP: URBAN WATER MANAGEMENT PROGRAMME

IHP’s Urban Water Management Programme (UWMP) generates approaches, tools and guidelines which will allow cities to improve their knowledge and analysis of the urban water situation to draw up more effective urban water management strategies.

The programme carries out the following activities:

- Developing solutions for more sustainable storm water collecting practices, taking into account intense rainfall events, increasing urban population size and ongoing detrimental changes on water resources from urban storm water.
- Minimizing urban storm water flow impact on water resources. This requires defining technical elements and managing rules to shift from the traditional engineering “optimization” goal to a more holistic “system resilience” goal.
- Consideration of both assets management in existing urban places and new based technological solutions in developing sub-urban areas.
- Ensuring that the minimum of polluted waters will reach the natural system even during more intense rainfall events. This is applicable both to combined and separated sewer systems.



BIODIVERSITY

Biodiversity is directly affected by climate change. Biodiversity within wetlands is a good example of such degradation. For many watersheds, there is an increased likelihood of warmer summers and therefore an increase in water temperatures with associated impacts on aquatic ecosystems and water quality.

ECOHYDROLOGY PROGRAMME

IHP's Ecohydrology programme is concerned with the impact of impact of climate change on biodiversity under specific socio-political constrains. The programme is concentrating on the level of environmental protection to be provided under climate change impacts. Developing countries will usually be least able or willing to consider the issue of the water required for environmental protection; their first priority is to take care of the immediate, basic needs of their population.

The initiative aims to raise awareness of these issues so that these two objectives are not contradictory and there are pathways to strike a balance under enhanced climate variability and climate change scenarios.



The cross-cutting agenda includes the following issues:

- The role the environment plays in securing water resources under different climate regimes
- Determining a value on the “natural” environment
- Identifying the impacts of environmental change on water resources

GROUNDWATER

Climate change affects groundwater recharge and discharge rates, as well as groundwater quality. Since knowledge of current recharge and levels in both developed and developing countries is poor, research efforts are underway to help us better understand the future impact of climate change on groundwater.

Groundwater is the primary source of drinking water for more than 1.5 billion people worldwide. In rural areas, groundwater is often the only source of water. In many countries groundwater is also important for sustaining agriculture, industrial uses, streams, lakes, wetlands, and ecosystems. Understanding the processes controlling the geochemical evolution of groundwater and differentiating between climate change and human impacts on groundwater quality are essential elements of sustainable integrated groundwater quality and land

use management, and are necessary in formulating an effective groundwater protection policy.

Direct human influences on groundwater quality are likely to be more important than climate change in the foreseeable future. Primary climatic stress issues have to do with recharge zones, especially for shallow aquifers, and sea water intrusion in coastal aquifers, related to sea level rise, in conjunction with other stresses.

At high latitudes, the thawing of permafrost causes changes in both groundwater levels and quality, due to increased coupling with surface waters. Since many groundwater bodies both charge into and are recharged from surface water, the impacts of surface water flow regimes are expected to affect groundwater. Increased precipitation variability may decrease groundwater recharge in humid areas.

GRAPHIC: GROUNDWATER RESOURCES ASSESSMENT UNDER THE PRESSURES OF HUMANITY AND CLIMATE CHANGE

IHP's GRAPHIC programme is working on the impact of climate change on groundwater systems. The programme is carried out in close cooperation with IHP National Committees, ICHARM, IGRAC, GEWEX, GEOS, IUGS, IAHS, UNU-HES, and UNESCO-IHE Institute for Water Education.

Activities include:

- Assessment of the impacts of global change (e.g. climate change and human pressures) on groundwater resources and support to Member States in addressing regional needs through global coordination
- Improvement of the understanding of how groundwater contributes to the global water cycle and evaluates the changes to groundwater storage and fluxes
- Better define growing population pressure on groundwater resources, global warming impacts on groundwater recharge rates, rising sea levels and saltwater intrusion
- Raise awareness of decision makers, implementers, users and the general public of the importance of groundwater as a store of freshwater to encourage improved protection and sustainable use
- Facilitating the county/regional groundwater assessment and exchange of information via seminars, workshops and conferences





THE IMPACT OF LAND USE CHANGE AND POPULATION GROWTH ON WATER RESOURCES

CHANGES IN LAND AND WATER USE PATTERNS HAVE SIGNIFICANT IMPLICATIONS AT LOCAL, REGIONAL AND GLOBAL LEVELS. MOST POPULATION GROWTH WILL OCCUR IN DEVELOPING COUNTRIES, MAINLY IN REGIONS THAT ARE ALREADY EXPERIENCING WATER STRESS, WITH LIMITED ACCESS TO SAFE DRINKING WATER.

Years of rapid population growth have put great pressure on the world's water resources through increased water demand and consumption as well as through the pollution resulting from water use. With the frequency and variability of extreme floods changing because of urbanization and land use changes, the number of people vulnerable to devastating floods is expected to rise. Therefore, disaster risk reduction actions are needed. The impact of land-use changes on extremes is an important issue within the seventh phase of IHP.

FRIEND WATER AND THE IMPACT ON FLOW REGIMES

The Asian Pacific FRIEND Water group has learned more about the impact of urbanization on flood risk through research on flood forecasting problems in China, urbanization and flooding in Japan, flooding due to rapid urbanization in Kuala Lumpur, and water quality management and flooding in Australia.

Consequently, flood mitigation solutions for the above mentioned problems have been developed to

decrease flood damages due to urbanization. Flood forecasting and early warning systems have been established, and flood inundation maps have been made available for cities with the most significant increases in urban areas.

A research group is working on identifying the relative role of climatic variability and land cover change on floods and low flows as a function of spatial scale. The group has summarized the state of the art on the subject, developed key scientific questions, is testing its research strategy in HELP basins and aims to provide a road map on how to address these issues. The group also acts as a catalyst for motivating communication and targeted research.

Research topics include:

- Analyzing methods to identify changes
- Looking into feedback mechanisms
- Analyzing generalization tools and potential of typologies of catchments and regions
- Researching transitional climate regimes
- Analyzing catchment processes and flow paths
- Assessing heterogeneity and scaling issues

THE IMPACT OF SOCIO-POLITICAL DYNAMICS ON WATER RESOURCES

GLOBAL CHANGE AND SOCIO-POLITICAL IMPACTS ON WATER RESOURCES INCREASE PRESSURE OVER WATER RESOURCES – LEADING TO COMPETITION AND EVEN CONFLICTS AMONG USERS AND SECTORS.

Forty percent of the world's population depend on the water resources of more than 270 transboundary river basins around the world. Conflicts can arise regarding quality, allocation, infrastructure, joint management, irrigation and other activities that are water-dependent.

PCCP: FROM POTENTIAL CONFLICT TO COOPERATION POTENTIAL



PCCP facilitates multi-level and interdisciplinary

dialogues in order to foster peace, cooperation and development related to the management of transboundary water resources.

The program aims to answer the following questions:

- How do we minimize conflicting environmental and human requirements under climate change threats?
- How do we resolve conflicts in the best way?
- How can legal tools address the challenges of global change in the context of transboundary water resources?

PCCP uses joint research and training activities to support cooperation processes around the use of shared water resources. These activities often allow the concerned parties to find opportunities to enhance their knowledge about the shared water resources, while also achieving progress on the cooperation, development and adaptation front, especially in the context of climate change threats.

The focus of the programme is on the development of tools which anticipate, prevent and resolve water conflicts.

PCCP is active in three areas:

Education and training: developing educational materials at the regional and global levels, and organizing multidisciplinary training courses;

Research: focusing on successful examples of cooperation, the causes of water conflicts, best practices as well as innovative techniques to manage them;

Process support: providing fora for dialogue and knowledge exchange on transboundary water resources.





THE WAY FORWARD

Addressing Challenges in a Changing and Interconnected World


The lessons learned from results achieved during this phase of the programme will be the basis for designing IHP-VIII which will become operational in 2014. Within the new phase of IHP, a hydrological change initiative could serve as an umbrella for existing programmes and bring together all aspects of global change to help us better understand the drivers and their impacts on water resources.








HOW WE WORK


UNESCO's **water family** operates as a global network that works together to implement the organization's strategic goals.


 UNESCO hosts the **IHP Secretariat** and provides seed funding that is multiplied many times over through cooperation with implementing partners. IHP is the only intergovernmental programme of the UN system devoted to water research, water resources management, education and capacity building. The IHP Secretariat serves UNESCO's 193 Member States, through the IHP National Committees, other governmental bodies, and academic and research institutions in the implementation of the programme.

 **UNESCO-IHE Institute for Water Education** – an integral part of UNESCO – is the educational arm.

 Twenty-six agencies of the UN system cooperate through the **World Water Assessment Programme (WWAP)** to provide an ongoing global assessment of the state of the world's freshwater resources. The programme is hosted and led by UNESCO.

 **UNESCO's Regional and Cluster Offices** assist in the implementation of IHP in the regions.

 **Water-related Institutes and Centres** under the auspices of UNESCO work on relevant thematic and geographic priorities in their areas of expertise. Since Member States have realized the potential of these centres, the network has been rapidly expanding.

 **UNESCO's Water-related Chairs** are established as teaching or research positions at universities or research institutes around the world.





ACRONYMS



CHRS	Center for Hydrometeorology and Remote Sensing	ISI	International Sediment Initiative
FRIEND	Flow Regimes from International Experimental and Network Data	IUGS	International Union of Geological Sciences
GEOS	Global Earth Observation Section	NGO	Non-Governmental Organizations
GEST	Global Evaluation of Sediment Transport	PCCP	From Potential Conflict to Cooperation Potential
GEWEX	Global Energy and Water Cycle Experiment	UN	United Nations
GRAPHIC	Groundwater Resources Assessment under the Pressures of Humanity and Climate Change	UNESCO	United Nations Educational, Scientific and Cultural Organization
G-WADI	Global Network on Water and Development Information in Arid Lands	UNU	United Nations University
GWES	Groundwater for Emergency Situations	UNU-EHS	United Nations University Institute for Environment and Human Security
GWSP	Global Water Systems Project	WATCH	Water and Global Change
HELP	Hydrology for Environment, Life and Policy	WMO	World Meteorological Organization
IAHS	International Association of Hydrological Sciences	WWAP	World Water Assessment Programme
ICHARM	International Centre for Water Hazards and Risk Management	WWDR	World Water Development Report
ICIWaRM	International Center for Integrated Water Resource Management		
IFI	International Flood Initiative		
IGRAC	International Groundwater Resources Assessment Centre		
IHP	International Hydrological Programme		
IPCC	Intergovernmental Panel on Climate Change		
ISDR	International Strategy for Disaster Reduction		

PHOTOS

FRONT COVER

Aerial photos of arctic tundra wetlands © shutterstock / George Burba ■ Boats in Pokhara Nepal Fewa Lake © shutterstock / Carlos Neto ■ Flood affected children eat snack with tea at flood relief camp established at Razzaqabad area in Karachi on Tuesday, August 31, 2010 © shutterstock / Asianet-Pakistan Rizwan Ali/PPI Images

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Green sunny field © shutterstock / Santiago Cornejo

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Boy drives a bike in desert © shutterstock / nmedia

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Crowded street scene from Old Delhi, India © shutterstock / JeremyRichards ■ City highways, Bangkok, Thailand, SE Asia © shutterstock / Vladimir Koletic ■ A poor streetside girl holding her toddler brother, in India © shutterstock / thefinalmiracle ■ Contrast of the Poverty and Wealth in Salvador of Bahia, Brazil © shutterstock / Vinicius Tupinamba ■ Burning pine needles in the forest © shutterstock / Oleg Dolenko

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Weary immigrants on a fishing boat intercepted by the Spanish coastguard off the island of Tenerife, July-October 2007 © UNHCR / A. Rodriguez ■ Garbage piled up on the coast of the ocean © shutterstock / Cozyta ■ Flood Brisbane Queensland declared natural disaster January 12, 2011 in Brisbane, Australia © shutterstock / andesign 101 ■ Black ploughed field under

blue sky © shutterstock / Mycola ■ Mining in the quarry © shutterstock / xtrekx

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Flood, poverty kids playing © shutterstock / Distinctive Images ■ Dead Trees in the forest around a lake with low water levels © shutterstock / Stephen Bonk

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Hills of SaPa Vietnam © shutterstock / Philip Date ■ The view on the Lofoten islands, Norway © shutterstock / Anilah

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Solitary tree flooded on sea water © shutterstock / Edwin Verin ■ A child carries household items while passing through the rubble of houses on August 29, 2010 in Nowshera, the homes were destroyed by flood waters © shutterstock / Asianet-Pakistan

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Dead tree and rocks in arid landscape © shutterstock / Suzanne Long ■ Poor mother with baby begging in the streets of New Delhi, India © shutterstock / Dhoxax

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Lake Sarez, Tajikistan © UNESCO / A. Mishra

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Man drinking water from tank, South India © shutterstock / Paul Prescott ■ Woman with water jug, Rajasthan, India © shutterstock / Kailash K Soni ■ Cambodian girl pumping water into a basin © shutterstock / Irina Ovchinnikova

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Soil erosion © shutterstock / Neil Bradfield

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Indian people work at Dhobi Ghat in Mumbai on November 5, 2009, Dhobi Ghat is the world's largest outdoor laundry. © shutterstock / Jan S.

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Herd of zebra at Masai Mara Kenya © shutterstock / Eric Isselée ■ Iguana in humid tropical environment of Amazonia © shutterstock / Natalia Macheda

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Aerial photos of arctic tundra wetlands © shutterstock / George Burba ■ A little Nepalese porter in the Himalaya on November 20, 2009 in Gorkha District, Nepal © shutterstock / Zzvet ■ Group of workers repaired water pipe © shutterstock / Mikhail Olykainen ■ Cascade falls over mossy rocks © shutterstock / Dvande ■ Inle Lake during monsoon season. Inle Lake is a freshwater lake located in the Shan Hills in Myanmar © shutterstock / Dirk Ott

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Boats in Pokhara Nepal Fewa Lake © shutterstock / Carlos Neto

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Flood affected women gather for food relief at a distribution area within a relief camp on August 28, 2010 in Hyderabad © shutterstock / Asianet-Pakistan

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Flood © shutterstock / Daniel Loretto ■ Child of the Lobi ethnic group August 12, 2009 in Gaoua, Burkina Faso © shutterstock / Hector Conesa ■ Army officials rescue a man from the flood hit area via helicopter on August 28, 2010 in Sukkur © shutterstock / Asianet-Pakistan

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Dried land near Brisbane © shutterstock / Ximagination ■ Portrait of two gorkhas children in national clothes on December 17, 2009 in Gorkha District, Nepal © shutterstock / Zzvet

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Navy officials evacuate flood affected people with the help of hovercraft at Behram Keti on August 22, 2010 in the Thatta District. © shutterstock / Asianet-Pakistan Aftab Ahmed /PPI Images ■ Flood-affected children fill their water pots at drinking water tanks on August 30, 2010 in Hyderabad © shutterstock / Asianet-Pakistan ■ Tuk-tuk taxi navigating through the flood after the heaviest monsoon rain in 20 years in the capital on August 14, 2009 in Bangkok, Thailand © shutterstock / Thor Jorgen Udvang

BACK COVER

Baltic coast with eroded beach and landslide after storm © shutterstock / Arvydas Kniuk

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