Economic Commission for Europe

Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Guidance on Water and Adaptation to Climate Change

UNITED NATIONS

Economic Commission for Europe

Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Guidance on Water and Adaptation to Climate Change

UNITED NATIONS

New York and Geneva, 2009

Note

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

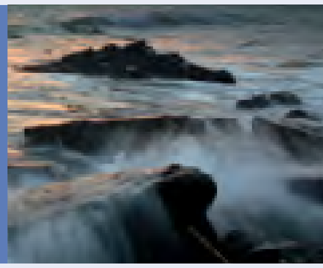
ECE/MP.WAT/30

UNITED NATIONS PUBLICATIONS

Sales No. 09.II.E.14

ISBN: 978-92-1-117010-8

Foreword



Climate change will result in significant impacts on our water resources and some of the effects are already visible now. Nearly all the countries in the region of the United Nations Economic Commission for Europe (UNECE), and beyond, are expected to be negatively affected by impacts ranging from increased frequency and intensity of floods and droughts, worse water scarcity, intensified erosion and sedimentation, reductions in glaciers and snow cover, sea level rise, and damage to water quality and ecosystems. Moreover, climate change impacts on water resources will have cascading effects on human health and many parts of the economy and society, as various sectors directly depend on water such as agriculture, energy and hydropower, navigation, health, tourism – as does the environment.

Adaptation to climate change is therefore a moral, economic and social imperative: action is needed now and water management should be a central element in the adaptation strategy of any country. Inaction could put sustainable development at risk: during the first years of the 2000s alone, thousands of lives and billions of dollars were lost through water-related disasters worldwide. On the other hand, the potential rewards of early action are high, as improved prevention, disaster preparedness and other adaptation measures, as well as adaptation of lifestyles, can vastly reduce these figures.

A particular challenge for water resources management is connected to the fact that almost half of the world's total land surface is drained by international river basins. Additionally, numerous groundwater resources are also transboundary. These transboundary waters create hydrological, social and economic interdependencies between countries. As both water and climate change do not respect borders, it adds an international dimension to climate change adaptation. This can have obvious security implications: namely, a growing potential for conflict arising from competition over dwindling water resources and the risk of countries taking unilateral measures with possible negative effects on riparian countries. Thus, in addition to the uncertainty over climate change impacts, countries are faced with uncertainty about their neighbours' reactions. Transboundary cooperation is therefore necessary to prevent negative impacts of unilateral measures and to support the coordination of adaptation measures at the river-basin level. This makes transboundary water resources management one of the most important challenges today and in the years to come.

The 1992 UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes provides a sound framework for transboundary cooperation, also in the context of adaptation to climate change. Developed under the Convention and its Protocol on Water and Health, this Guidance aims to spur climate change adaptation that takes into account the transboundary dimension of water management. It is a novel and innovative advancement: the first document of its kind to focus on the transboundary setting and illustrate the steps needed to develop an adaptation strategy. Based on the concept of integrated water resources management, the Guidance provides advice to decision makers and water managers on how to assess impacts of climate change on water quantity and quality, how to perform risk assessment, including health risk assessment, how to gauge vulnerability, and how to design and implement appropriate adaptation strategies.

The Guidance is a collaborative achievement: more than 80 experts from national authorities, academia, non-governmental and international organizations contributed to its preparation. Building on the principles of the Convention and on the experience gained in its implementation, the Guidance places special emphasis on the specific problems and requirements of transboundary basins, with the objectives of preventing, controlling and reducing transboundary impacts of national adaptation measures and thereby preventing and resolving possible conflict. The Guidance also underlines the benefits of cooperation in adapting to climate change in transboundary basins: sharing the costs and benefits of adaptation measures, better managing uncertainty through the exchange of information, broadening the knowledge base, and enlarging the range of measures available for prevention, preparedness and recovery, thus allowing us to find better and more cost-effective solutions.

Only concerted and coordinated action will enable countries to deal with the uncertainties of climate change and to tackle its impacts effectively. We trust that this Guidance will help countries to jointly cope with climate change impacts in the UNECE region and around the world. As the first product of its kind in the region – and worldwide – it is hardly an endpoint for the work on adaptation to climate change in transboundary basins. Rather, it is an initial step towards the planning and implementation of sound, cooperative adaptation strategies and measures.

Ján Kubiš
Executive Secretary,
United Nations Economic
Commission for Europe

Tineke Huizinga-Heringa
Vice Minister of Transport, Public
Works and Water Management of
the Netherlands

Sigmar Gabriel
Federal Minister for the Environment,
Nature Conservation and Nuclear
Safety of Germany

Stefania Prestigiacomo
Minister for the Environment,
Land and Sea of Italy

PREFACE

Hydrometeorological records and climate projections provide abundant evidence that water resources are vulnerable and can be strongly affected by climate change, with wide-ranging consequences for human societies and ecosystems. Nevertheless, very few countries have developed adaptation strategies so far. The fact that many water bodies cross boundaries, especially in the UNECE region, means that risks and challenges are shared and that solutions therefore need to be coordinated. Transboundary cooperation in developing adaptation strategies is currently, however, almost non-existent.

Recognizing the urgency of the issue, at its fourth session in November 2006 in Bonn, Germany, the Meeting of the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) decided to develop the present Guidance on Water and Adaptation to Climate Change. Work on the Guidance was carried out under the Convention's Task Force on Water and Climate, jointly led by the Netherlands and Germany, in cooperation with the Task Force on Extreme Weather Events under the Protocol on Water and Health, led by Italy. The Guidance has a special focus on transboundary issues and health aspects and includes numerous case studies. It is intended to guide Parties and non-Parties to the Convention and to the Protocol on Water and Health in the implementation of the Convention's and Protocol's provisions in the context of climate change.

The Guidance is based on experience and good practices in the UNECE region. Its preparation relied on a broad consultative process, involving national authorities, academia, NGOs and international organizations. A drafting group with multidisciplinary competences and an extensive expert review were decisive in its development. Its drafting was also informed by a survey conducted in countries with economies in transition, which explored adaptation needs and measures already undertaken, and by the findings of the international workshop on "Water and Adaptation to Climate Change: Joining Efforts to Adapt" (Amsterdam, 1–2 July 2008), organized by the Governments of the Netherlands, Germany and Italy in cooperation with UNECE and the World Health Organization Regional Office for Europe. The Amsterdam workshop allowed for sharing experiences related to the benefits of and mechanisms for transboundary cooperation in adaptation activities, as well as institutional, policy, legal, scientific and financial aspects of adaptation in water management and water depending sectors, including cross-cutting issues such as education. The Guidance benefited from and inspired the work done at the level of the European Union that started under the German presidency in 2007 and culminated with the publication of the White Paper "Adapting to climate change: Towards a European framework for action" in April 2009 and the preparation of the guidance document "River basin management in a changing climate" developed under the Common Implementation Strategy of the EU Water Framework Directive.

However, existing experience with climate change adaptation in the transboundary context is still very limited. As climate change adaptation is a new and uncertain process, practice is needed to advance our knowledge. This Guidance should be seen as a first step in a long-term process. By adopting it, the Parties to the Water Convention commit to its implementation at all levels. An important next step will be the practical actions that will be based on the Guidance. The lessons learned, good practices and experience that will come from implementing the Guidance and promoting climate change adaptation in transboundary basins will help extend our knowledge base and improve our ability to cope with current and future climate change. Exchanging such experience with climate change adaptation is crucial to enhancing the adaptive capacity of countries both within the UNECE region and beyond. The Convention will continue to be an important platform for sharing experience at the pan-European level and for building cooperation on one of the key issues facing the region.

Acknowledgements

This publication would not have been possible without the generous contributions of many governments, individuals and international organizations. The UNECE Water Convention secretariat expresses its gratitude to the members of bodies under the Convention and the Protocol on Water and Health, as well as the expert reviewers and all those who provided case studies, contributions and comments.

The secretariat particularly thanks the members of the editorial group who drafted and edited the text of the Guidance:

Jos Timmerman, RWS Centre for Water Management, the Netherlands
Meike Gierk, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany
Luciana Sinisi, Superior Institute for Environmental Protection and Research (ISPRA), Italy
Mikhail Kalinin, Central Research Institute for Complex Use of Water Resources, Belarus
Natalya Agaltseva, Research Hydrometeorological Institute, Uzhydromet, Uzbekistan
Edgar Pirumyan, Ministry of Nature Protection, Agency of Water Resources Management, Armenia
Giacomo Teruggi, World Meteorological Organization
Henk Van Schaik, Cooperative Programme on Water and Climate, the Netherlands
Sonja Koeppel, UNECE Water Convention secretariat
Francesca Bernardini, UNECE Water Convention secretariat
Laura Altinger, UNECE

The secretariat also wishes to heart fully praise the efforts of the drafting group that was responsible for preparing and reviewing the Guidance. The drafting group, in addition to the members of the editorial group, was also composed of:

Joost J. Buntsma, Ministry of Transport, Public Works and Water Management, the Netherlands (chair)
Roger Aertgeerts, World Health Organization Regional Office for Europe
Marloes Bakker, Cooperative Programme on Water and Climate, the Netherlands
Ella Behlyarova, UNECE Water Convention secretariat
Zsuzsanna Buzas, Ministry of Environment and Water, Hungary
Benedetta Dell'Anno, Ministry for the Environment, Land and Sea, Italy
Tanja Dubrovin, Finnish Environment Institute, Finland
Zsuzsanna Engi, West-Transdanubian Environmental and Water Authority, Hungary
Christian Göldi, on behalf of Swiss Federal Office for the Environment
José Luis Martin Bordes, United Nations Educational, Scientific and Cultural Organization
Inmaculada Paniagua, Ministry of the Environment, and Rural and Marine Affairs, Spain
Avinash Tyagi, World Meteorological Organization

Case studies, comments and other contributions were provided by:

Nadezhda Alexeeva, Secretariat of the Ramsar Convention on Wetlands
Andrew Allan, United Nations Educational, Scientific and Cultural Organization Centre for Water Law, Policy and Science, University of Dundee, United Kingdom
Miguel Antolin, Ministry of the Environment, and Rural and Marine Affairs, Spain
Laurens Bouwer, Institute for Environmental Studies (IVM), the Netherlands
Nicholas Bonvoisin, UNECE
Lisa Brodey, United States Permanent Mission, Geneva
Graham Bruce, Pembina Trails School Division, Manitoba, Canada
Roman Corobov, Eco-Tiras International Environmental Association of River Keepers, Republic of Moldova
Ad de Roo, Joint Research Centre of the European Commission
Suzanne Ebert, WWF-World Wide Fund For Nature
Itay Fischhendler, the Hebrew University of Jerusalem, Israel
Maria Galambos, Ministry of Environment and Water, Hungary
Maria Grechushnikova, Moscow State University, Faculty of Geography, Hydrological Department, Russian Federation
Diana Heilmann, International Commission for the Protection of the Danube River
Balazs Horvath, European Commission, Environment Directorate-General
Heide Jekel, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany

Mike Keil, Ofwat, United Kingdom
Marco Keiner, UNECE
Ville Keskisarja, Ministry of Agriculture and Forestry, Finland
Arend Kolhoff, Commission for Environmental Assessment, the Netherlands
Flavia Loures, WWF-World Wide Fund For Nature
Xianfu Lu, Secretariat of the United Nations Framework Convention on Climate Change
John Matthews, WWF-World Wide Fund For Nature
Helen McCarthy, European Commission, Environment Directorate-General
Hanna Mela, Finnish Environment Institute, Finland
Ute Menke, RWS Centre for Water Management, the Netherlands
Bettina Menne, World Health Organization Regional Office for Europe
Magdalena Muir, Coastal & Marine Union (EUCC)
Doubravka Nedvedova, Ministry of the Environment, Czech Republic
Henk Nijland, Ministry of Transport, Public Works and Water Management, the Netherlands
Saba Nordstrom, Organization for Security and Co-operation in Europe
Markku Ollila, Finnish Environment Institute, Finland
José Rocha Afonso, Water Institute, Portugal
Tobias Salathe, Secretariat of the Ramsar Convention on Wetlands
Federico San Martini, United States Department of State, Bureau of Oceans, Environment & Science, Office of Environmental Policy
Shervin Shakuri, Ministry of Health, Republic Centre of Hygiene and Epidemiology, Azerbaijan
Anna Sikharulidze, United Nations Development Programme/Global Environment Facility Project, "Second National Communication of Georgia to the United Nations Framework Convention on Climate Change"/Tbilisi State University, Georgia
Jari Silander, Finnish Environment Institute, Finland
Michael Stanley-Jones, UNECE
Thomas Stratenwerth, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany
Caroline Sullivan, Southern Cross University, New South Wales, Australia, and School of Geography and the Environment, Oxford University, United Kingdom
Sandor Szalai, Hungarian Meteorological Service (OMSZ), Hungary
Pulatkhon D. Umarov, Scientific Information Centre of the Inter-State Coordination Water Commission of Central Asia
Manuel Varela, Ministry of the Environment and Rural and Marine Affairs, Spain
Luis Veiga da Cunha, New University of Lisbon, Portugal
Sibylle Vermont, Swiss Federal Office for the Environment, Switzerland
Jeremy Wates, UNECE
Ben van de Wetering, International Commission for the Protection of the Rhine
Michael van der Valk, Cooperative Programme on Water and Climate, the Netherlands

The following experts who reviewed the Guidance greatly improved it with their comments and contributions:

Mike Acreman, Centre for Ecology and Hydrology, Wallingford, United Kingdom
Vahid Alavian, World Bank
Chee Keong Chew, Water, Sanitation, Hygiene and Health, World Health Organization
Victor Dukhovny, Scientific Information Centre of the Inter-State Coordination Water Commission of Central Asia
Gerald Farthing, Deputy Minister of Education, Citizenship and Youth, Manitoba, Canada
Alberto Garrido, Technical University of Madrid, Spain
Bruce Gordon, Water, Sanitation, Hygiene and Health, World Health Organization
Gyula Holló, Ministry of Environment and Water, Hungary
Bohumir Kriz, Institute for Public Health, Czech Republic
Jose Martin-Alonso, Barcelona Water Supply Company, Spain
Marcus Moench, Institute for Social and Environmental Transitions, United States of America
Stephane Simonet, World Water Council
Eugene Stakhiv, United States Army Corps of Engineers
Rob Swart, Alterra, the Netherlands
Bulat Yessekin, Expert for Central Asia, Kazakhstan

The Guidance was edited by Alex Kirby, United Kingdom, and by Christopher Edgar, UNECE. It was designed by Lisa Dodson. Olga Carlos provided additional technical support in the Guidance preparation process.

The UNECE secretariat wishes to thank specifically Natalya Agaltseva, Uzbekistan, with the support by Mikhail Kalinin, Belarus, for the translation of the Guidance into Russian.

Finally, the UNECE secretariat gratefully acknowledges the funding by the Ministry of Transport, Public Works and Water Management of the Netherlands, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany, as well as the financial contributions by the Swiss Federal Office for the Environment (for translation) and the Italian Ministry for the Environment, Land and Sea.

While every effort was made to name all contributors, the UNECE secretariat regrets if any individual or organization has been overlooked in the lists above.

Contents

List of figures, tables and boxes

List of Figures

List of Tables

List of Boxes

List of Acronyms and Abbreviations

CER	Certified emission reduction
CIS	Common Implementation Strategy (for the European Union Water Framework Directive)
CRED	Centre for Research on the Epidemiology of Disasters
DMP	Drought management plan
EC	European Commission
EEA	European Environment Agency
EIA	Environmental impact assessment
EM-DAT	Emergency Events Database
EU	European Union
GCM	General Circulation Model
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse gas
GIIF	Global Index Insurance Facility
GIS	Geographical information system
GMES	Global Monitoring for Environment and Security
ICPDR	International Commission for the Protection of the Danube River
ICPR	International Commission for the Protection of the Rhine
ICZM	Integrated coastal zone management
IFM	Integrated flood management
IHR	International Health Regulations
INSPIRE	Infrastructure for Spatial Information in the European Community
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction (of the United Nations)
IWRM	Integrated water resources management
JRC	Joint Research Centre (of the European Commission)
MDGs	Millennium Development Goals
M&E	Monitoring and evaluation
NMHS	National Meteohydrological Services
NWP	Nairobi work programme on impacts, vulnerability and adaptation to climate change (under the UNFCCC)
ODA	Official Development Assistance
Ofwat	Office for Water Services in the United Kingdom
PES	Payment for ecosystem services
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat
RBMP	River basin management plan
RCC	Regional climate centre
RCM	Regional climate model
RCOF	Regional climate outlook forum
SEA	Strategic environmental assessment
SRES	Special Report on Emissions Scenarios
TCIP	Turkish Catastrophe Insurance Pool
TNMN	Transnational Monitoring Network
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
VA	Vulnerability assessment
Water Convention	Convention on the Protection and Use of Transboundary Watercourses and International Lakes
WEAP	Water Evaluation and Planning System
WFD	Water Framework Directive (of the European Union)
WHO	World Health Organization
WMO	World Meteorological Organization
WHYCOS	World Hydrological Cycle Observing System
WSP	Water safety plan

Key Messages

The world needs to adapt to climate change in water management without delay. Hydrometeorological records and climate projections provide abundant evidence that water resources are vulnerable and can be strongly affected by climate change, with wide-ranging consequences for human societies and ecosystems. Although climate change can also have positive consequences for some countries, such as a prolonged growing season, overall nearly all UNECE countries are expected to be negatively affected. The impacts will vary greatly from region to region. They include an increased frequency and intensity of floods and droughts, worse water scarcity, intensified erosion and sedimentation, reduction in glacier and snow cover, sea level rise, salinization, soil degradation, and damage to water quality, ecosystems and human health. Many countries are already experiencing some impacts and are paying the economic and social price. Attempts to mitigate climate change have begun, but they will take too long to show results any time soon. So it is both urgent and cost-effective to start adapting now.

Uncertainty should never be a reason for inaction. Action and research on adaptation should be pursued simultaneously. What we know about climate change is qualified by a level of uncertainty. All the same, we can identify trends that allow us to act. A twin-track approach, combining immediate action and further research, is therefore recommended. Water management and water-related policies and measures need to be adapted now to climate change on the basis of what we know already. At the same time, we need to do more research into the effects of climate change to deepen our knowledge. National and international funding organizations should give priority to water management research focusing on climate adaptation. This obviously requires continuous communication and interaction between science and policy. Pursuing this approach requires political leadership, especially when funds are limited.

Adaptation needs to be flexible. This is required by the uncertainties which exist about the direction and nature of change the climate is causing in hydrological systems. Interventions chosen should be flexible enough to deliver maximum benefits under a range of conditions instead of being designed for what are thought to be the "most likely" future conditions. If conditions change again, or if the changes prove different from those expected today, the measures taken should be capable of changing in step. Win-win, no-regret and low-regret measures should have priority. Another approach to uncertainty is to reduce the current sources of vulnerability, for example by increasing resilience and the capacity for adaptation. Ecosystems provide a wide range of services, including climate and flood regulation, so increasing their resilience is vital.

The process of developing and implementing adaptation measures should build on learning-by-doing. The steps taken may not achieve the desired results, or they may have unexpected side-effects, while the effects of climate change may also run counter to expectations. This again highlights the need for flexibility, and for continuous evaluation to see whether the actual results really match those desired. Only in this way can strategy changes be made in good time. Pilot projects are a helpful way to develop and implement adaptation strategies.

Water is central to many different sectors that directly depend on water being available and of high quality. Therefore, water management can limit or enhance adaptation of water-related sectors. Climate change's impacts on water are expected to have cascading effects on human health and on many parts of the economy. They include agriculture (increased demand for irrigation and forestry), energy (reduced hydropower potential and cooling water availability), recreation (threats to water-linked tourism), fisheries, and navigation. Serious impacts on biodiversity also loom.

Implementing integrated water resources management supports adaptation. The core principles of integrated water resources management (IWRM) include planning at the river basin level, strong intersectoral cooperation, public participation and making the best use of water resources. The same principles also underpin any effective adaptation strategy. So incorporating climate change effects into IWRM and encouraging its wide adoption will also advance adaptation.

Any adaptation policy needs to consider climate change as one of many pressures on water resources. Others include population growth, migration, globalization, changing consumption patterns, and agricultural and industrial developments. These different stressors interfere with each other and can have positive and negative feedbacks. This means adaptation should be coordinated with other water management measures and integrated in an overall strategy. Scenarios can be helpful in assessing the possible effects of different pressures and in developing water management measures.



Effective adaptation to climate change requires a cross-sectoral approach including at the transboundary level, in order to prevent possible conflicts between different sectors and to consider trade-offs and synergies between adaptation and mitigation measures. Uncoordinated sectoral responses can be ineffective or even counterproductive, because a response in one sector can increase the vulnerability of another sector and/or reduce the effectiveness of its adaptation responses. Climate change adaptation should be integrated into existing policy development, in planning, programmes and budgeting, across a broad range of economic sectors – a process generally called "mainstreaming". And mitigation measures should be considered in the light of their consequences for adaptation options, and vice versa. For example, biofuel production as a mitigation measure can have negative impacts on water supply and food production, while building settlements in flood-prone areas not only increases vulnerability, but can also hinder the implementation of adaptation measures.

Barriers to adaptation in the legal, institutional and policy spheres must be removed. Legislation should be developed flexibly, to be able to cope with different possible climate impacts. Legislation should not present barriers for adaptation, and should be flexible enough to accommodate continuing environmental and socio-economic changes. It should actually foster or promote adaptation. Existing legislation and transboundary agreements may need revising. As a first step, existing legislation, from the local to the transboundary levels, should be assessed for its capacity to support adaptation. For example, legislation prohibiting the re-use of wastewater may need to be changed into legislation that sets requirements for its safe use. Transboundary agreements should include provisions for addressing flow variability and the availability of safe water.

Implementing national legislation and international commitments supports adaptation. A number of international agreements include provisions and have developed tools that can support the development of adaptation strategies. Countries should take into account and build on such provisions to maximize results and ensure the coherence of the policies and measures they adopt. The EU Water Framework Directive (WFD), for instance, builds on the principles of IWRM and the ways countries should cooperate in water management. Together with its guidelines on climate change adaptation, the concepts of the WFD support the development of adaptation strategies.

Transboundary cooperation is both necessary and beneficial in adapting to climate change. It is necessary throughout the entire process of developing and implementing an adaptation strategy. International basins constitute about half of the Earth's land surface. The fact that many water bodies, especially in the UNECE region, cross boundaries means that risks and challenges are shared and that solutions therefore need to be coordinated. Transboundary cooperation in developing adaptation strategies is currently almost non-existent. However, it is not only necessary to ensure that unilateral measures do not do significant damage to riparian countries. It is also essential to make sure they offer benefits to all riparian Parties, for example by sharing the costs and benefits of adaptation measures or by reducing uncertainty through the exchange of information. Measures should therefore be taken only if they are the product of wide consultation and sound science. Transboundary cooperation can broaden our knowledge base, enlarge the range of measures available for prevention, preparedness and recovery, and so help to find better and more cost-effective solutions. The UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) offers a sound framework for cooperation at the transboundary level on adaptation.

When planning adaptation across boundaries, riparian countries should focus on preventing transboundary impacts, sharing benefits and risks in an equitable and reasonable manner and cooperating on the basis of equality and reciprocity. By considering costs and benefits on a basin scale, new options for adaptation open up that can prove more cost-effective. Countries' differing capacities also need to be taken into account.

Knowledge and experience need to be exchanged to enhance the capacity of countries to adapt. Climate change is a relatively new phenomenon, and we do not yet know everything about its effects on the quantity and quality of water resources and its related influence on human health. Little experience is available yet in developing adaptation strategies and measures, and even less at the transboundary level. Knowledge developed by countries and experiences in implementing measures in basins, both successful and less successful examples, can help other countries to reduce risks, including environment-related health-risks.

Ensuring that data and information are readily available is crucial for making climate projections and identifying vulnerable groups and regions. So sharing information, including that from early warning systems, between countries and sectors is essential for effective and efficient climate change adaptation. Data collection should cover all aspects of the hydrological cycle and should take into consideration the needs of the end-users, but also include social and economic information. Early warning systems are essential for preparedness for extreme weather events and should be developed at the transboundary level, to allow for the effective sharing of information. They should also be closely linked to seasonal and long-term climate and weather forecast systems. Monitoring and observation systems should be capable of adapting to the changes in information needs that could develop in the future. By sharing information, countries and sectors can extend and deepen their understanding of climate change effects, improve their models, and better assess the vulnerabilities connected to climate change, especially in a transboundary basin. Information exchange, or even better, joint information collection, is therefore imperative to build the knowledge base needed to face the effects of climate change. Riparian countries should work on common scenarios and models to develop a joint understanding of possible impacts.



Effective adaptation strategies are a mix of structural and non-structural, regulatory and economic instruments and measures, education and awareness-raising to tackle the short-, medium- and long-term impacts of climate change. In many cases no single measure can fully address the effects of climate change. Successful adaptation strategies therefore combine a variety of measures that target different groups and timescales. Any adaptation strategy should include measures in all the steps of the adaptation chain: prevention, improving resilience, preparation, reaction and recovery. Risk management should be made the priority, not crisis management.

Adaptation measures should strive to be cost-effective, environmentally sustainable, culturally compatible and socially acceptable. Prioritization of measures should be based on the results of vulnerability assessments, costs and benefits assessments, as well as on development objectives, stakeholder considerations and the resources available. As a first step, available measures should be described comprehensively, in terms of their benefits, risks, costs, possible side-effects and uncertainties. Secondly, measures need to be compared and ranked. Ways of doing this include systematic qualitative analysis, semi-quantitative analysis in order to compare different attributes or parameters, and full quantitative analysis of risks, costs and benefits.

Water supply and sanitation, especially during extreme weather events, require special attention in adaptation policy, as they are essential for good health.[1] Health hazards may be caused by extreme temperatures, an increase in water temperature, water scarcity, and chemical and biological contamination of water used for different purposes (including food production and processing). Adaptation, especially in the local and transboundary context, should take account of such events. Increasing water scarcity may limit access to water for sanitation, reduce the self-cleaning capacity of sewers and limit the ability of natural ecosystems to assimilate wastes. Flooding may cause contamination and, especially in large cities, storm-water overflows and pollution.

Adaptation may be costly, but it is much more cost-effective to start it now, because costs will be much higher once the effects of climate change are irreversible. Paying for adaptation should be done by a mix of public and private funding. Pricing mechanisms and markets can help to achieve a more efficient allocation of water resources, but equity should never be neglected. Mechanisms like insurance can play an important role in adaptation when extreme weather is involved. They should be part of a country's disaster risk reduction and prevention strategy.

Stakeholder participation is crucial for all steps of the development and implementation of adaptation strategies and measures. From identifying information needs to vulnerability assessment, planning and choosing priority adaptation measures, the knowledge, capacity and views of everyone involved are crucial to ensure sound, effective and sustainable adaptation. Including utilities managers is also crucial, to ensure that the water supply and sewerage services continue to function under changing conditions.

Education, capacity-building and communication are imperative for effective adaptation. Ignorance or lack of awareness can be important causes of vulnerability. Working to ensure that both water professionals and society-at-large are well informed about causes and consequences of climate change will enhance their ability to cope and can also help to prevent unsuitable adaptation.

Climate change and the need for adaptation is also an opportunity for innovation and new technologies. The need for adaptation requires a paradigm shift: thinking outside the box. This may stimulate alternative and innovative approaches. In particular, it is crucial to shift from a supply-side approach to a more sustainable, "demand-side" approach to water resource management, focusing on conserving water and using it more efficiently. In countries where climate change also has positive impacts, society should aim to maximize the benefits from these impacts, for example using a prolonged growing season to increase the number of annual harvests.

[1] See the draft Guidance on Water Supply and Sanitation in Extreme Weather Events, developed under the Protocol on Water and Health.

INTRODUCTION

Water resources are vulnerable and already affected by climate change and variability with wide-ranging consequences for societies, their health, economies and the natural environment.

Many countries in the UNECE region have already experienced severe impacts from extreme events and disasters. It is likely that anthropogenic climate change (change caused by human activities) will exacerbate the severity and frequency of those events, as well as affecting the region's water resources in other ways, e.g. through changing precipitation patterns. The need is to adapt now.

The transboundary nature of water resources in the UNECE region means that risks and challenges are shared and thus solutions in adaptation need to be coordinated between all states in a transboundary basin.

This Guidance aims at providing step-by-step advice for the development of sound adaptation strategies and thereby supporting countries in their implementation of the Water Convention and its Protocol on Water and Health in the context of climate change.

Hydrometeorological records and climate projections provide abundant evidence that water resources are vulnerable and can be strongly affected by climate change, with wide-ranging consequences for human societies and ecosystems.

Nearly all United Nations Economic Commission for Europe (UNECE) countries are expected to be harmed by the impacts of climate change. Impacts will vary considerably from region to region and even from basin to basin. The first Assessment of transboundary rivers, lakes and groundwaters in the UNECE region[2] has shown that in many basins climate change impacts are being seen already.

The socio-economic impacts of climate change are significant: in the period 2000–2006, the worldwide frequency of disaster from extreme climatic events increased by 187 per cent compared with the previous decade, accounting for 33,000 deaths and 1.6 billion people affected (2000-2008). In the same period, global economic damages for flooding events and heavy storms were estimated to be about US$ 25 billion[3] (figure 1).

---

[2] UNECE, 2007.
[3] EM-DAT: The Office of Foreign Disaster Assistance/ Centre for Research on the Epidemiology of Disasters (OFDA/CRED) International Disaster Database, www.emdat.net, Université Catholique de Louvain, Brussels, Belgium.

Increased precipitation (rain, sleet and snow) intensity and variability will increase the risks of flooding and drought. The frequency of heavy precipitation is likely to increase during the 21st century, increasing the risk of floods and intensified erosion. At the same time, the proportion of land surface that will suffer extreme drought is projected to increase.

Water supplies stored in glaciers and snow cover are projected to decline in the course of the century, thus reducing water availability during warm and dry periods. In many regions supplied by meltwater from major mountain ranges winter flows will increase due to higher temperatures and thus earlier snowmelt. On the other hand, water flow in low flow periods during the summer may be further reduced. Groundwater recharge is also expected to be affected in different ways depending on the region. Because of increasing temperatures the composition of forests is expected to change which may increase the risk of erosion and landslides in mountainous areas, but also have other effects on the water cycle in the plains, e.g. through reduced water retention in the soil.

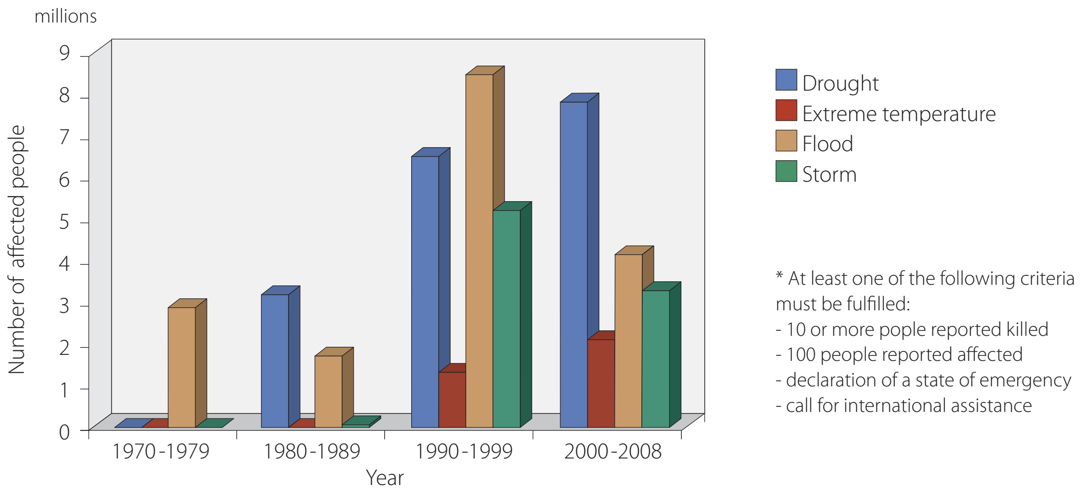
Higher water temperatures and changes in extreme events, including more and more intense floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt – and also cause thermal pollution, with possible damage to ecosystems, human health, and water system reliability and operating costs.

In addition, sea-level rise is projected to extend areas of salinization of groundwater and estuaries resulting in a decrease of water availability for ecosystems and humans.

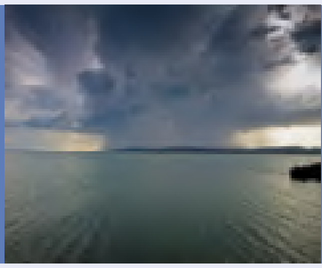
In some cases, climate change might have positive impacts such as increased growth rates and food conversion efficiencies, increased length of growing season, species range expansion, and the availability of new land due to decreased ice cover. Society should aim to understand and maximize the benefit from these positive impacts which can support adaptation, for example by using a prolonged growing season to increase the number of annual harvests.

Globally, the harm caused by climate change to fresh-water systems is expected to outweigh the benefits. At the global level, by the 2050s, the area of land affected by increasing water stress caused by climate change is projected to be more than double that with decreasing water stress. Areas in which run-off is projected to decline obviously face a reduction in the value of the services their water resources can supply. Increased annual run-off in some areas is projected to lead to increased total water supply. But in many regions this benefit is likely to be counterbalanced by the damage caused by increased variability in precipitation and seasonal run-off, shifts in water supply and water quality, and flood risks.

Figure 1:Total number of people affected by drought, extreme temperatures, storms, and flood disasters in the UNECE region (1970-2008)



Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.net, Université Catholique de Louvain, Brussels, Belgium. Adapted by the Institute for Environmental Protection and Research (ISPRA, Italy).



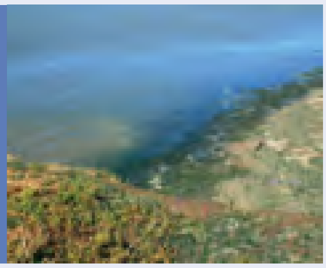
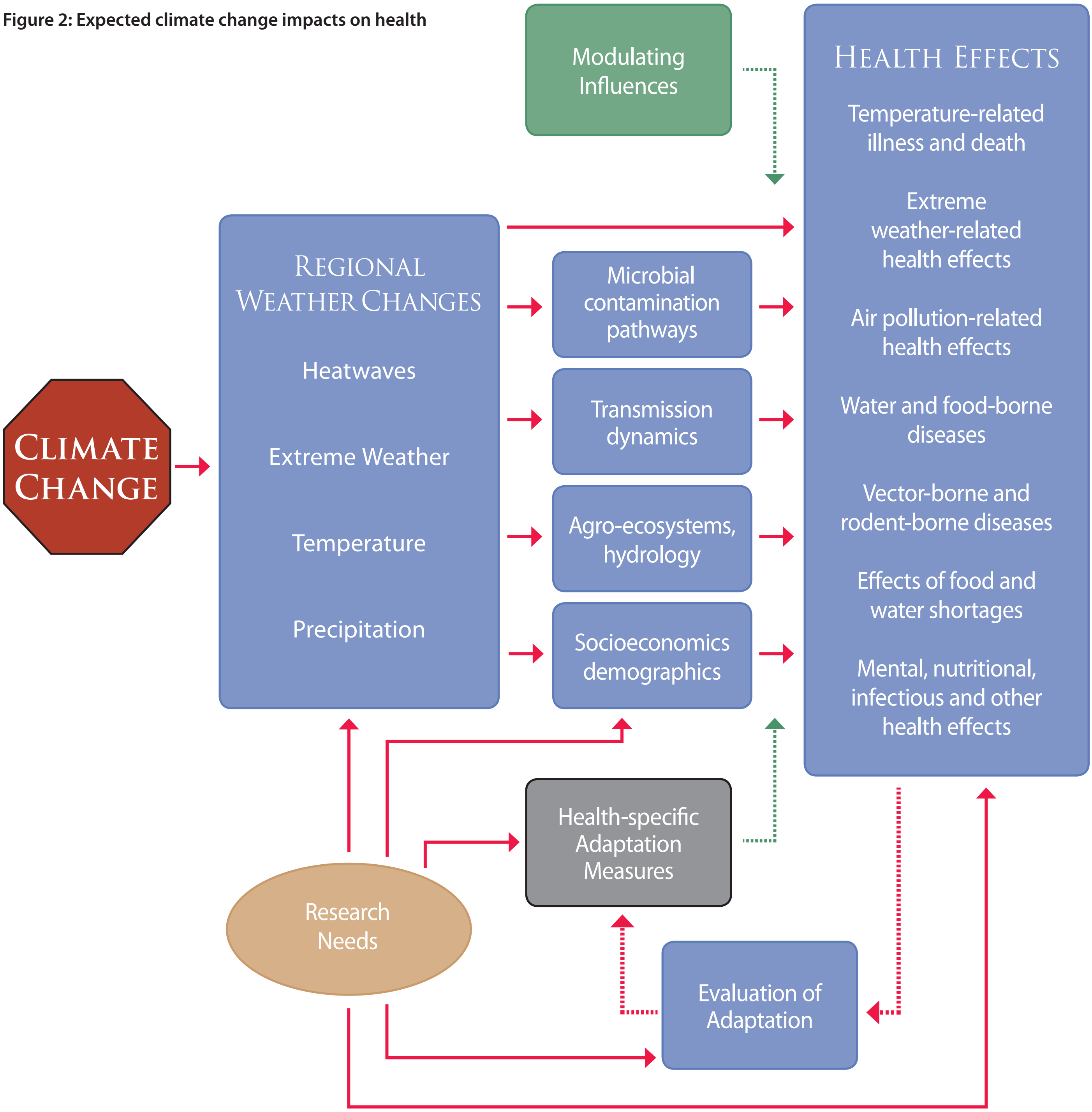


Table 1: Risks for water and other sectors through climate change

PHENOMENON	EXAMPLES OF MAJOR PROJECTED IMPACTS BY SECTOR, MAINLY THROUGH WATER			
	Water resources	**Agriculture, ecosystems**	**Health**	**Industry and society**
Heavy precipitation events	• Flooding • Adverse effects on quality of surface and groundwater due to sewer overflows • Contamination of water supply • Water scarcity may be relieved	• Damage to crops • Soil erosion • Inability to cultivate land due to waterlogging of soils	• Increased risk of deaths, physical injuries and infectious, respiratory and skin diseases • Risk of psychological disorders	• Disruption of settlements, commerce, transport and societies due to flooding, migration • Pressures on urban and rural infrastructures • Loss of property
Higher variability of precipitation, including increased droughts	• Changes in run-off • More widespread water stress • Increased water pollution due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution • Salinization of coastal aquifers	• Land degradation • Lower yields/crop damage and failure • Increased livestock deaths • Increased risk of wildfire	• Increased risk of food and water shortage; • Increased risk of malnutrition; • Increased risk of water- and food-borne diseases	• Water shortages for settlements, industry and societies • Reduced hydropower generation potentials • Potential for population migration
Increased temperatures	• Increased water temperatures • Increase in evaporation • Earlier snow melting • Permafrost melting • Prolonged lake stratification with decreases in surface layer nutrient concentration and prolonged depletion of oxygen in deeper layers • Increased algae growth reducing dissolved oxygen levels in the water body which may lead to eutrophication and loss of fish • Changes in mixing patterns and self purification capacity	• Less water available for agriculture, more irrigation needed • Changes in crop productivity • Changes in growing season • Changes in species composition, organism abundance, productivity and phenological shifts, for example earlier fish migration	• Changes in vector-borne diseases • Increase of fatalities due to heatwaves, and decreased personal productivity • Increased risk of respiratory and skin diseases due to ozone and pollen	• Risk for infrastructure fixed in permafrost • Degradation of freshwater quality

(based on Bates et al. 2008, IPCC 2007)

Figure 2: Expected climate change impacts on health



Source: World Health Organization (http://www.who.int/globalchange/climate/en/).

Water is central to many different sectors hence the impacts of climate change are expected to have far-reaching effects on society. Economic sectors which are projected to be most affected are agriculture (increased demand for irrigation and forestry), energy (reduced hydropower potential and cooling water availability), recreation (water-linked tourism), fisheries and navigation. Because of the importance of these sectors for national and individual welfare, climate change impacts on water have important direct and indirect effects. Serious impacts on biodiversity also loom (see table 1).

Climate change and variability and associated changes in the available water resources and their quality are also responsible for increased health risks through direct effects (e.g. drowning or trauma in floods, post-traumatic mental disorders in natural disasters) and exposure to health hazards caused by growing contamination of water (e.g. by pathogens, waste and toxic chemicals), lack of household hygiene, reduction of food safety, and an increase in the number and geographical distribution of disease- carrying vectors. These changes can result in an increase in emerging and re-emerging infectious diseases. Figure 2 illustrates expected climate change impacts on health, including those related to water.

A special concern is linked to the disruption of water supply and sanitation systems during extreme events that might result in an increase in water-borne infectious diseases. Specific advice on this issue is given in the *Guidance on Water Supply and Sanitation in Extreme Weather Events,* developed under the Protocol on Water and Health.

Adverse effects of climate change on water aggravate the impacts of other stresses and pressures, such as changing consumption and production patters, land use change, urbanization and population growth. Responses to climate change and other pressures may have irreversible long-term impacts, e.g. land degradation caused by inappropriate long-term irrigation.

There are considerable differences in climate change projections across the UNECE region and a wide range of issues and vulnerabilities, reflecting differing hydrological situations (as an example see figure 3). Furthermore, the impacts vary in time and space: some impacts are on a daily/local scale (e.g. lower oxygen content), others are at longer/larger scales (e.g. changes in algal blooms over weeks or months, changes in species composition over many years, groundwater level variations and alterations to groundwater flow directions). Overall, in Southern Europe, the Caucasus and Central Asia, climate change is projected to lead to higher temperatures and more severe and prolonged droughts and to reduced water availability, hydropower potential, summer tourism and, in general, crop productivity. In Central and Eastern Europe, summer precipitation is projected to decrease, thereby causing higher water stress. Climate change can also have positive impacts such as a prolonged growing season in parts of the UNECE region. In Northern Europe, climate change is initially projected to bring positive effects, including some benefits such as reduced demand for heating, increased tourism, increased crop yields and increased forest growth. However, as climate change continues, negative impacts are likely to outweigh the benefits.

Current water management practices may not be robust enough to cope with the future impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope with current hydrologic variability which can lead to extensive flood and drought damage. In addition, natural changes can be exacerbated by illegal activities such as unauthorized well-drilling which underlines the need for strong management rules and their enforcement.

Thus climate change impacts on freshwater resources put at risk sustainable development, economic growth, poverty reduction, production and availability of food, and the health of people and ecosystems, thus the ability to achieve the Millennium Development Goals.

Countries with economies in transition and less developed countries are among the most vulnerable to the adverse effects of climate change, and widespread poverty limits their ability to adapt.

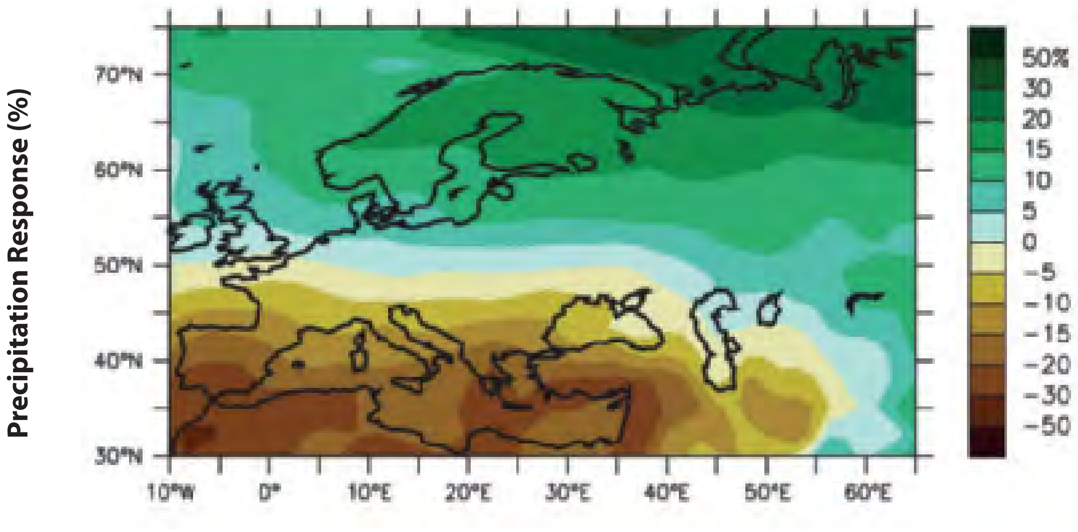
Adaptation to climate change is consequently indispensable and urgent since the climate is already changing in some respects, and mitigation will take too long to show effects. Further climate change throughout this century and beyond is almost certain even if global mitigation efforts prove successful. In addition, it is more cost-effective to start preparing for adaptation now.

Adaptation represents an important challenge for all countries, especially for those with economies in transition, but few have developed adaptation strategies so far. Knowledge and experience of adaptation in a transboundary context is especially lacking.

In the UNECE region the situation is further complicated by the transboundary nature of the water resources. The impacts of climate change on the more than 150 transboundary rivers, 50 major transboundary lakes and more than 170 transboundary groundwater systems will affect riparian countries differently, creating even stronger interdependence and calling for cooperative solutions. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) requires Parties to establish such cooperation; this is also necessary and beneficial for non-Parties.

For this reason, the Meeting of the Parties to the Water Convention, at its fourth session (Bonn, Germany, 2006), decided to assist Governments in developing adaptation strategies at different government levels by elaborating a Guidance on water and adaptation to climate change. Following this decision, the present Guidance was prepared by the Task Force on Water and Climate under the Water Convention, in close cooperation with the Task Force on Extreme Weather Events, under the Convention's Protocol on Water and Health.

Figure 3: Percentile changes (averaged over 21 models) in annual mean precipitation between the periods 1980 -1999 (observed precipitation) vis-à-vis the period 2080-2099 (expected precipitation).



Source: Figure created from merging figures 11.5 and 11.9 from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, Working Group I – Scientific Basis (Christensen et al. 2007).

Aims and scope

The Guidance is intended to guide Parties to the Water Convention and Parties to the Protocol on Water and Health in the implementation of the Convention and Protocol provisions within the context of climate change. The Guidance is not legally binding and does not supersede the legal obligations arising from the Convention and the Protocol.

This Guidance aims to support decision makers from the local[4] to the transboundary and international level by offering advice on the challenges caused by climate change to water management and water-related activities and thereby to develop adaptation strategies. It builds on the concept of IWRM, which many countries are in the process of implementing. Climate change adds to the complexity of its implementation. The Guidance addresses the additional challenges of climate change but does not address IWRM as a whole.

The Guidance addresses not only extreme events but also water management in general under the influence of climate change and variability and related uncertainty.

The Guidance aims to put special emphasis on the specific problems and requirements of transboundary basins, with the objective of preventing, controlling and reducing transboundary impacts of national adaptation measures and thereby preventing and resolving possible conflicts related to the impact of climate change on water resources. However, the Guidance is based on the existing very partial experience on adaptation to climate change in the transboundary context and reflects this incomplete knowledge.

The Guidance is a general strategic roadmap towards adaptation of water management to climate change but needs to be tailored to specific local situations. Therefore it does not provide a detailed overview of all possible measures or elements of an adaptation strategy since these depend on the local and sectoral context.

Annex 2 provides a check list for guidance-users for self-assessment of their level of progress towards adaptation to climate change.

Target group

The key target groups of the Guidance are decision makers and water managers working in ministries and other authorities, in particular at the transboundary level. It also targets those responsible at the national and local level for relevant health-related issues, such as the provision of safe drinking water and adequate sanitation, the safe use of water from new sources, the prevention of vector-borne diseases and food safety and security in water and disaster management.

The document can also be of interest to officials, managers and stakeholders (both private and public) of other sectors with a direct relevance to water and health, such as the agricultural sector, the forestry sector, the food sector (particularly aquaculture), the tourism sector, inland water transport, electricity production, fisheries, nature conservation etc. It also provides some knowledge for those involved in building disaster-resilient communities

The Guidance was specifically prepared to assist Governments, joint bodies and other actors in the UNECE region, with a focus on countries with economies in transition. However, it can also be applied, as appropriate, in other regions.

[4] For the purpose of this Guidance, "local" refers to all levels of territorial unit below the level of the State.

Key steps of the Guidance

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required. A range of barriers limits both the implementation and effectiveness of adaptation measures. The capacity to adapt changes over time and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology etc.

The Guidance provides a framework to develop step-by-step an adaptation strategy (see Figure 4) taking into account the usual barriers. The key-steps for the development of an adaptation strategy illustrated in the Guidance are:

Establish the policy, legal and institutional framework (chapters 2 and 3)

- Assess existing international commitments, policies, laws and regulations for water and related sectors (e.g. agriculture, health care, hydropower development, inland water transport, forestry, disaster management, nature conservation) in relation to their effectiveness in reducing climate-induced vulnerabilities and to their capacity to support the development of adaptation strategies and then revise and complement them as needed;

- Define the institutional processes through which adaptation measures are or will be planned and implemented, including where decision-making authority lies at the transboundary, national and local levels and what the links are between these levels;

Understand the vulnerability of society (chapters 4, 5 and 6)

- Ascertain the information needed to assess vulnerability;

- Gauge the future effects of climate change on the hydrological conditions of the specific transboundary basin in terms of water demand and water availability, including its quality, based on different socio-economic and environmental scenarios;

- Identify the main current and climate-induced vulnerabilities that affect communities, with particular attention paid to water resources and the health-related aspects;

- Determine, through participatory processes, the needs, priorities and adaptive capacities of different;

Develop, finance and implement an adaptation strategy (chapters 7 and 8)

- Identify potential adaptation measures to reduce vulnerability to climate change and climate variability by preventing negative effects, by enhancing the resilience of natural, social and economic systems to climate change, or by reducing the effects of extreme events through preventive, preparatory, reactive and recovery measures. Measures should include both structural and non-structural measures as well as the financial means and the institutional changes necessary to implement successful adaptation processes;

- Based on participatory processes, prioritize the potential measures and investments needed taking into account the financial and institutional resources and other means and knowledge available to implement them;

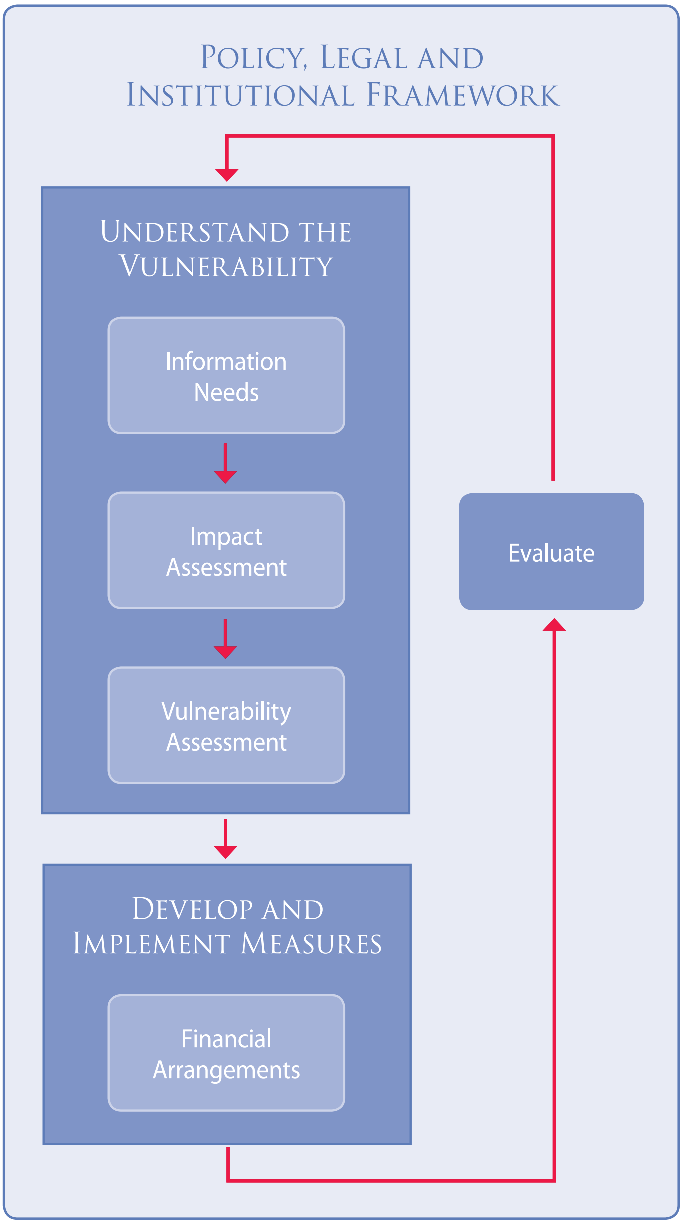
- Ensure the step-by-step implementation of the adaptation strategy, in accordance with determined priorities, including coping measures from the local to the State and transboundary level;

Evaluate (chapter 9)

- Determine whether the measures are implemented and if those measures that are implemented lead to reduction of vulnerability; if not, adjust the measures accordingly;

- Assess whether the scenarios as applied materialize in practice and adjust them accordingly.

Figure 4: Framework and steps for the development of an adaptation strategy



Chapter 1

Core Principles and Approaches

Adaptation can and should build upon the numerous water management measures which are already available and implemented.

Adaptation needs to be cost-effective, environmentally sustainable, culturally compatible and socially acceptable.

Any adaptation policy should consider climate change in the context of the many other increasing pressures on water resources such as population growth, globalization, changing consumption patterns and industrial development.

Adaptation policies should be developed within the context of IWRM, which involves planning at the level of the river basin, strong intersectoral cooperation, public participation and optimization of the use of water resources.

Effective transboundary cooperation should be ensured at all relevant stages of decision-making, planning and implementation.

Adaptation is a not a "once only " exercise, but rather a continuous, long-term process to be integrated into all levels of planning. Currently, short-term thinking is still too frequent.

Climate change is characterized by a high level of uncertainty and risk; various methods can be used to reduce or manage uncertainty.

In any case uncertainty cannot be a reason not to act. Instead, adaptation should start now while at the same time the knowledge base can be increased through focused research (a twin-track approach).

Adaptation policy planning should consider and prevent possible conflict between different water-related sectors. Tradeoffs between adaptation and mitigation strategies should also be avoided.

Adaptation should also include a disaster risk reduction strategy that must be grounded in local knowledge and communicated broadly so that every citizen is aware about possible personal adaptation measures. Health response systems can help in this regard.

In their actions to design and implement adaptation measures and policies, Parties should be guided by the following principles and approaches:

Following the principles of sustainable development, adaptation policies and measures should consider social, economic and environmental concerns and ensure that the needs of the present generation are met without compromising the needs of future generations. Implemented measures need to be cost-effective, environmentally sustainable, culturally compatible and socially acceptable.

Equitable access to water resources should be the first priority of any water adaptation strategy and be ensured through participatory and transparent governance and management.

Water resources are affected by numerous and inter-linked pressures such as population growth, globalization of agricultural markets, changing consumption patterns, growing energy and resource demand, and energy and food prices variation, which differ from region to region. Indeed, with the possible exception of extreme events (such as droughts and floods), climate change is unlikely

to be the primary stressor on water; population growth and changing consumption patterns are believed to be the primary drivers. Therefore climate change impacts on water resources should be considered together with these other pressures or stressors and adaptation should be coordinated with other water management measures and be integrated in an overall strategy in order to adapt to global changes. Different stressors interfere with each other and can have positive and negative feedbacks. Some measures can even pursue several goals simultaneously, e.g. climate proofing of existing water supply systems can be done in combination with ensuring access to water for those that do not enjoy it. On the other hand, in some cases, different stressors require different response strategies especially if a certain group is clearly responsible for a certain pressure and can thus be involved in the solution (see box 1).

IWRM should be applied as well as Integrated Coastal Zone Management (ICZM) and Integrated Flood Management (IFM). These entail:

- Applying the river basin approach. This includes integrating land, rivers, lakes, groundwaters and coastal water resources as well as their interaction with other ecosystems, in particular upstream and downstream dimensions;

- Optimizing the use of water resources to meet changing supply and demands. This involves conducting assessments of surface and groundwater supplies, analysing water balances, adopting safe wastewater reuse and the use of rainwater, evaluating the environmental impacts of distribution and use options, adopting cost recovery policies, using water-efficient technologies and establishing decentralized water-management authorities; and

- Groundwater as an important resource should be used, where appropriate, sustainably and in an integrated manner with surface water. This can be achieved through: (a) developing and promoting a more accurate understanding of the socio-ecological value

of groundwater as well as the nature and scale of the consequences of its unsustainable use; (b) developing and disseminating research knowledge on promising technologies and management approaches; and (c) exploring sustainable solutions and sharing them with the main strategic actors involved in national and regional groundwater systems.

Strong interdepartmental (inter-ministerial) and intersectoral cooperation with the involvement of all relevant stakeholders is a precondition for effective decision-making, planning and implementation. Effective cooperation should successfully integrate both top-down and bottom-up approaches. Authority should be employed responsibly and stakeholders should have an impact on the process. Public participation should be ensured and gender issues should be taken into account when appropriate.

Box 1: Inter-relation Between Climate Change and Other Water Stressors

Many non-climatic drivers affect freshwater resources, for example changes in population, consumption and production patterns – in particular food consumption – economy (including water pricing), technology, and societal views regarding the value of freshwater ecosystems. Thus climate change is one of many factors that influence future water stress. However demographic, socio-economic and technological changes can possibly play more important roles on most time scales and in most regions. For example, in the 2050s, differences in the population projections of the four IPCC Special Report on Emissions Scenarios (SRES) scenarios would have a greater impact on the number of people living in water-stressed river basins than the differences in the climate scenarios. The other stressors also determine vulnerability to climate change: for example, while climate change may influence the intensity and frequency of extreme weather events as well as the migration of disease vectors, the impacts of such events depend mostly on socioeconomic vulnerability, which in turn reflects a range of variables such as demographics, development patterns, economic growth and wealth distribution, and local environmental conditions.

Another important challenge is that the different stressors are closely interrelated and strongly affect each other. Some possible interconnections are:

Land use changes/urbanization: current land use practices and increasing urbanization often result in pollution, sealing of surfaces and a loss of forests and wetlands. These lead to increased run-off resulting in an increased risk of flooding, sedimentation and eutrophication, all of which aggravate climate change impacts.

Agriculture: current agricultural practices often require high water consumption because of inappropriate crop selection (cultivation of water- intensive crops in warm arid regions), application of outdated irrigation technologies, etc. Climate change impacts such as reduced water availability add to this pressure. In addition, intensive agriculture often harms surface and groundwater quality and biodiversity, decreasing the resilience of ecosystems and their capacity for adaptation.

Urbanization causes among others, the formation of urban heat islands (increased temperature in a metropolitan urban area when the land surface is modified by urban development and waste heat generated by heating in buildings) and therefore leads to increased water use. The increase in sealed surface also increases the surface run-off and reduces infiltration, thus decreasing water availability.

Demographic changes, including population growth and migration are certainly one of the main causes of increased water use. In addition, these changes are mainly concentrated in coastal areas which are already under high water stress and where climate change is expected to have the highest impact, including through salinization of groundwater.

Growing energy consumption: Biofuel production requires significant amounts of water. Nuclear power plants (often favoured currently because of their low carbon dioxide (CO_2) emissions in operation) and all thermal power plants require huge amounts of water for cooling, which adds to the water temperature increase caused by climate change and might have significant impacts on biodiversity and water chemistry. Since energy demand, especially for cooling, is expected to increase as the climate changes, more water will be needed for cooling in power stations.

The **state of infrastructure** like dams and irrigation systems also plays an important role and, if inadequate, can lead to major risks of water waste, exacerbating water stress, and also to increased risks of major accidents.

Climate change impacts will also exacerbate some of the other stressors. For example, it is expected to lead to more climate refugees who may cause further urbanization. Increasing temperatures and changes in hydrology will also cause changes in natural land use or vegetation in some regions.

Although the exact extent of these interconnected stresses and the environmental and human response to them is still largely unknown, they should be regarded as a system with positive and negative feedback loops, synergies, and cumulative effects and ways of interfering with each other. So climate change impacts and possible adaptation measures always have to be considered and assessed in the context of other driving factors. For example, in some cases of high population density, restricting urban development in flood-prone areas may be impossible to implement and enforce if the population is growing quickly. Current sewers may not be the appropriate wastewater treatment technology for areas with high population growth. Coordinating adaptation measures with IWRM plans and other development plans is crucial for successful adaptation.

Source: Zimmermann, J.B., J.R., Mihelcic and J. Smith, 2008. Global stressors on water quality and quantity. In *Environmental Science and Technology* 42 (12): 4247-4254.

For transboundary basins, effective cooperation should be ensured at all relevant stages of decision-making, planning and implementation,

- In accordance with article 2 of the Water Convention, riparian Parties shall prevent, control and reduce transboundary impacts, for example when developing adaptation strategies and measures against climate change;

- Moreover the Parties shall take all appropriate measures to ensure that transboundary waters are used in a reasonable and equitable way. Thus the principles of reasonable and equitable use shall also be at the basis of any decision on adaptation measures within a transboundary basin. When there is a conflict of uses between riparian States, and all the conflicting uses are considered reasonable, weighing all relevant uses, factors and circumstances can help to resolve the conflict. Ultimately, solutions should as much as possible maximise the overall benefits to all riparian States, whilst at the same time protecting the long-term sustainability of the resource. Close cooperation is necessary in the whole process;

- In doing this, Parties shall cooperate on the basis of equality and reciprocity, in particular through bilateral and multilateral agreements and the relevant joint bodies to develop common research, harmonized policies, programmes and strategies to adapt to climate change;

- The principle of solidarity should be applied, which means that risks, costs and responsibilities are shared between riparian States, also taking into account their capacities, the risk entailed, the effectiveness of the different options and the obligations under the Convention.

Climate change is characterized by a high level of uncertainties and risks, in particular about the magnitude, timing and nature of the changes. Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions. However, the consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. Decision makers are not used to such uncertainty when dealing with other problems. Various methods are available to reduce or manage the uncertainty. These include sensitivity analysis, risk analysis, simulation and scenario development. In addition, because of the uncertainty about future climate variations, the reduction of current vulnerabilities is vital, so that society can better cope with today's risks.

In no case can uncertainty be a reason for inaction; but decisions for effective adaptation require analysis, reflection, and consultation. The goal of water management under uncertain conditions that can occur in surprising and nonlinear ways should be to increase the adaptive capacity by learning from and better coping with these uncertain developments. This aim for improved learning and adaptation, in addition to control, adds an extra dimension to the integrated and participative approach and is generally referred to as adaptive water management.

Design and implementation of adaptation strategies takes considerable time, particularly if substantial changes are needed. This underlines the need for action now, and not waiting for 'perfect data' to emerge. Adaptation should start immediately while at the same time knowledge should be improved so as to permit improved action in future through focused research (the twin-track approach).

No-regret and low-regret options should be considered as a priority. No-regret options are measures or activities that will prove worthwhile even if no (further) climate change occurs. For example, early warning systems for floods, drought management plans (DMP) and water safety plans (WSP) will be beneficial even if the frequency of the extreme events does not increase as expected. Low-regret options are options

whose associated costs are relatively low and which can potentially bring large benefits under projected future climate change.

Adaptation is a not a "one-off " exercise, but rather a continuous, long-term process to be integrated in all levels of planning and operation or implementation. Currently, short-term thinking is still too frequent. Long-term adaptation should be fostered and any short-term measures should also take into account the long-term perspective.

Sound science and best available information should be used as a basis for any decision on adaptation measures. Best available and innovative technology should be used if sustainable. However, technical and structural solutions will not be sufficient to address climate change; behavioural, legal and political measures are needed as well. As climate change raises threats of harm to human health and the environment, the precautionary principle should be applied and preventive actions taken even if some cause-and-effect relationships are not yet fully proven scientifically. In the face of uncertainties, a precautionary approach might even result in a more stringent emissions reduction target and/or adaptation response. However, "over-adaptation" should also be avoided, which underlines the need for prioritizing low- and no-regret measures.

Ecosystems such as wetlands deliver a wide range of services that contribute to human well-being, including those relating to climate change mitigation and/or adaptation which are often vital for water quality and availability. However, these ecosystems are themselves threatened by climate change and overuse. Ecosystem preservation and restoration is therefore very important for increasing adaptive capacity and reducing vulnerability.

The impacts of climate change are locally specific and change over time. Any measures to cope with the effects of climate change should therefore be developed at the appropriate level (global, local, regional) taking into account the physical and socio-economic conditions and capacities (both financial and human). Measures should be planned for the short, medium and long-terms.

Strengthening institutions for land and water management is crucial to effective adaptation and must build on principles of participation of civil society, gender equality, subsidiarity and decentralization. Successful adaptation requires public participation and interactions between multiple levels of government: regional, national, local and at the level of the transboundary basins, as adaptation at one level can strengthen, or weaken, adaptive capacity and action at other levels. A range of civil society and business sector organizations should also be involved. Working in partnership is a core principle of effective adaptation. Identifying and engaging with the relevant stakeholders is critical for success as they bring knowledge and skills to the process. The more comprehensive that knowledge and skills base is, and the more informed they are about the adaptation process, the more likely adaptation is to succeed. Stakeholders can also help to identify potential conflicts or synergies between adaptation and other initiatives. Social and institutional innovation is also a key aspect of an efficient adaptation framework. This may imply revising governing arrangements, decision-making mechanisms, budgetary processes, etc.

Disaster risk management should be part of preventive measures in adaptation strategies, so a disaster risk reduction strategy should be developed based on local knowledge. It should be communicated broadly so that every citizen is aware about possible personal adaptation measures. Health response systems can help to increase knowledge and awareness.

Inappropriately designed adaptation can also damage other policy areas, such as energy, health, food security and nature conservation. For instance, the increased use of reservoirs may under some conditions create breeding grounds for vector-borne diseases; or the increased use of water for irrigation may lead to lack of water for the river's ecological functions. So adaptation, rather than being concentrated in one sector should essentially be ubiquitous and dispersed across all socio-economic sectors – including water, health, agriculture, infrastructure as well as nature conservation – each of which presents its own challenges.

Adaptation to climate change must also occur through the prevention and removal of maladaptive practices. Maladaptation means measures that do not succeed in reducing vulnerability but instead increase it. Examples of measures that prevent or avoid maladaptation include better management of irrigation systems and removal of laws that can inadvertently increase vulnerability, such as the relaxation of building regulations on coasts and in floodplains.

So the development of adaptation options needs to be conducted across multiple water-dependent sectors. Environmental impact assessment (EIA) and strategic environmental assessment (SEA) are important tools for an integrated approach to the protection of the environment, for analyzing the environmental effects of proposed plans, programmes and other strategic actions and to integrate the findings into decision-making. These tools should be used when developing adaptation measures and strategies, but SEA and EIA procedures may themselves need revision to be able to respond optimally to climate change. In particular, the health risk of climate change adaptation options should be assessed before adopting any strategy.

There can be synergies and trade-offs between mitigation and adaptation which should be taken into account. Often the two approaches are disconnected, but it can be useful to consider them in an integrated manner in order to maximize synergies and avoid negative effects:

- In the long term, mitigation measures can reduce the magnitude of the impacts of global warming on water resources, in turn reducing adaptation needs. However, mitigation measures can also have considerable negative side effects for adaptation, such as increased water requirements for bio-energy crops, if projects are not sustainably located, designed and managed;

- Conversely, adaptation measures can also have negative effects for mitigation. This is often because many adaptation measures increase energy use, which, if no renewable sources are used, will increase greenhouse gas (GHG) emissions and hence mitigation requirements (see box 2 on possible trade-offs between adaptation and mitigation). Examples are desalinization, irrigation, and energy-intensive construction of flood protection infrastructure.

The overall positive or negative balance for both climate change adaptation and mitigation depends on the design and management of the specific measure, on the specific location, and on many other factors (see also box 2). So mitigation aspects should be evaluated in adaptation projects and vice versa through environmental impact assessment and other techniques. Mitigation and adaptation strategies should be developed and implemented in an integrated way, avoiding the possibility that any measure taken could exacerbate the problem or have other undesirable side-effects. Impacts must be assessed individually for each specific case.

Estimating costs and benefits is a prerequisite for ranking a concrete measure and including it in the budget or in a wider adaptation programme. The costs of inaction that could lead to a number of environmental and socio-economic effects (e.g. lost jobs, population displacement and pollution) should also be considered. Adaptation should be integrated into budgetary planning across all sectors and at all levels.

Box 2: Possible Trade-offs Between Adaptation and Mitigation Measures

Examples of proposed mitigation measures and possible impacts on water resources

MITIGATION MEASURE	POSSIBLE RISKS FOR WATER RESOURCES	POSSIBLE POSITIVE EFFECTS	POSSIBLE REMEDIES AND COMMENTS
Carbon dioxide capture and storage	Degradation of groundwater quality due to leakage of CO_2 from injection and abandoned wells, leakage across faults and ineffective confining layers; local health and safety concerns due to release of CO_2	Reduction of atmospheric CO_2 , Possible re-use of CO_2 for industrial purposes or in production of biomass	Careful site selection, effective regulatory oversight, appropriate monitoring of the condition of the storage sites, remediation methods to stop or control CO_2 releases. Further research is needed.
Geothermal energy extraction	Chemical pollution of upper layers of fresh aquifers and waterways due to trace amounts of dangerous elements such as mercury, arsenic, and antimony, concerns regarding land subsidence.	Decreased GHG emission in the atmosphere	Appropriate location of facilities, re-injection techniques, use of appropriate techniques. Further research is needed.
Large-scale biofuel production	Increased water demand, enhanced leaching of pesticides and nutrients leading to contamination of water, biodiversity impacts, conflicts with food production and land use changes, leading to indirect effects on water resources, increased vulnerability to droughts	Possible positive impacts through reduced nutrient leaching, soil erosion, run-off and downstream siltation	Energy production and GHG mitigation potentials of energy crops depend on many factors, including land availability. Appropriate location (the previous land cover should be of lower value), appropriate design and management are essential. Further research is needed.
Hydro-electric power plants	Ecological impacts on existing river ecosystems and fisheries for example due to changes in flow regime, water temperature regime, oxygen concentrations and evaporation social impacts.	Possibly flow regulation, flood control, availability of water for drinking and irrigation, recreation, navigation	Mitigation effect of large hydropower dams is contested. Appropriate location and management, smaller hydro-power plant size, multi-purpose use of dams for irrigation and hydropower, and comprehensive impact assessment can help to remedy negative effects.
Land management for soil carbon conservation	Enhanced contamination of groundwater with nutrients or pesticides via leaching under reduced tillage	Erosion control, improved water and air quality, increase of food production, reduction of siltation of reservoirs and waterways	Depends on region and conditions, use of innovative methods of precise agriculture e.g. nutrients are injected into the subsurface precisely according to needs of the crop.
Agricultural intensification e.g. crop rotation	Crops with higher water demand		
Evaporative cooling in buildings	High water demand	Reduced energy demand	Reducing the cooling load by optimizing building shape and orientation

Examples of adaptation measures in the water sector which can have negative impacts on climate change mitigation

ADAPTATION MEASURE IN WATER MANAGEMENT	POSSIBLE NEGATIVE IMPACTS FOR GHG EMISSIONS	POSSIBLE REMEDIES AND COMMENTS
Desalinization of saline water for water supply	High energy needs	Mitigation impact depends on energy source, therefore use desalinization only if no other choices, and use renewable energy
Reservoirs/ hydropower plants	Can emit GHGs as water conveys carbon in the natural carbon cycle and due to the rotting vegetation	Mitigation effect depends on many factors, including depth of reservoir. Multi-purpose dams and appropriate location and management are recommended, but more research is needed
Irrigation	High water and energy needs	Use efficient irrigation techniques, drought-resistant crop varieties. Mitigation effect depends on energy source

Sometimes it is possible to combine the reduction of vulnerability with mitigation of greenhouse gas emissions. For example, by increasing water efficiency or decreasing water demand energy is saved and at the same time vulnerability to droughts decreased. Soil enhancement stores carbon and can make soils less subject to erosion. In spatial planning (e.g. of river basins) much can be gained, e.g. by designing new urban areas in a way that would be both climate-proof and energy efficient. Reduced deforestation and reforestation (with suitable tree species) and wetland restoration can at the same time reduce GHG emissions and have positive impacts on water quality and quantity, reduce flood risks and enhance the stability of water resources. Some agricultural practices such as crop rotations, high-yielding varieties, integrated pest management, adequate fertilization or water-table management also have ancillary benefits. Low water use toilets and ecological sanitation approaches can both reduce water needs and reduce possible GHG emissions from wastewater. More generally, enhanced capacity and managerial support to deal with climate change in river basin management institutions will have benefits for both approaches.

There are five pragmatic suggestions for broadening climate policy to take into account the linkages between adaptation and mitigation: (1) avoid trade-offs when designing policies for mitigation or adaptation, (2) identify synergies, (3) enhance response capacity by enhancing the generic capacity to both adapt and mitigate through non-climate policies (education, institutional capacity, etc.), (4) develop institutional links between adaptation and mitigation – e.g. in national institutions and in international negotiations, and (5) mainstream adaptation and mitigation considerations into broader sustainable development policies.

References: Swart, R. and F. Raes, 2007. Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? *Climate Policy* 7 (4): 288–303.

Kundcewicz et al., 2007 and Bates et al., 2008.

CHAPTER 2


Addressing Climate Change
The United Nations and the World at Work
Thematic Debate of the United Nations General Assembly
ETHIOPIA
COLOMBIA
CHILE
CONGO
BAHRAIN
BELARUS
URUGUAY
UZBEKISTAN
ROMANIA
RWANDA
SUDAN
SWEDEN

International Commitments

A number of international agreements include provisions and have developed tools that can support the development of adaptation strategies.

Countries should take into account and build on such provisions so to maximize results and ensure coherence of policies and adopted measures.

2.1 United Nations Framework Convention on Climate Change

The main commitments related to adaptation in the United Nations Framework Convention on Climate Change (UNFCCC) are contained in article 4, which requires Parties to develop, implement and regularly update national and, when necessary, regional programmes of measures to facilitate adequate adaptation to climate change. Parties should cooperate in preparing for adaptation. They are requested to elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, as well as for the protection and rehabilitation of areas affected by floods or drought and desertification. Parties shall also take climate change considerations into account in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments and adaptation planning, to minimize adverse effects on the economy, public health and the quality of the environment arising from projects or measures to mitigate or adapt to climate change. So, adaptation and mitigation obligations are linked and should reinforce each other. In addition, developed countries are requested to assist developing countries in particular in their efforts to adapt to climate change impacts.

The Nairobi work programme on impacts, vulnerability and adaptation to climate change, launched in 2005 under the Subsidiary Body for Scientific and Technological Advice (SBSTA) of UNFCCC, aims to help all countries improve their understanding and assessment of the impacts of climate change and to make informed decisions on practical adaptation actions and measures (box 3).

Box 3 : The Nairobi Work Programme Under UNFCCC

The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP) under the SBSTA of the UNFCCC aims to assist all countries, in particular developing countries including the least developed countries and small island developing States, to improve their understanding and assessment of impacts, vulnerability and adaptation, and to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound, scientific, technical and socioeconomic basis, taking into account current and future climate change and variability. To achieve these aims, NWP has nine areas of work: (a) methods and tools; (b) data and observations; (c) climate modelling, scenarios and downscaling; (d) climate-related risks and extreme events; (e) socio-economic information; (f) adaptation planning and practices; (g) research; (h) technologies for adaptation; and (i) economic diversification.

Under the guidance of the Chair of the SBSTA and with participation from Parties, organizations and experts, the UNFCCC secretariat facilitates the implementation of the NWP through a wide range of mandated activities. These include submissions from Parties and organizations, synthesis reports, web-based information such as the adaptation practices interface, workshops and expert meetings. The online adaptation practices interface enables an exchange of experiences, practices and projects. Calls for action have been developed which aim to facilitate the implementation of recommendations, by Parties and other stakeholders, resulting from the Nairobi work programme workshops and expert meetings. Action pledges provide an interactive way for Parties, international governmental organizations, non-governmental organizations (NGOs) and research institutes to identify and commit publicly to undertake activities towards the objectives and expected outcomes of the NWP.

The NWP has become a global framework on adaptation involving Parties and over 150 intergovernmental and non-governmental organizations, the private sector and other adaptation stakeholders. During the second phase of the programme, which started in 2008, there is a greater emphasis on the further engagement of organizations, particularly those that focus on community, national and regional actions and on education, training and awareness-raising.

Source: http://unfccc.int/nwp



2.2 World Health Organization International Health Regulations

The International Health Regulations (IHR) entered into force on 15 June 2007 as a new legal framework to better manage collective defences to detect disease events (including e.g. major industrial accidents) and to respond to public health risks and emergencies. The IHR require State Parties to notify a potentially wide range of events to the World Health Organization (WHO) on the basis of defined criteria indicating that the event may constitute a public health emergency of international concern. Parties are further required to ensure that their national health surveillance and response capacities meet certain functional criteria as included in WHO guidelines and have a set time frame in which to meet these standards. The IHR therefore constitutes an important additional defence framework for coping with the health impacts of climate change in general, and with changes in incidence and outbreaks of water-related diseases in particular.

2.3 Relevant United Nations Economic Commission for Europe Conventions and Protocols

2.3.1 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention)

Although the UNECE Water Convention does not explicitly mention climate, it represents one of the most crucial legal frameworks in the UNECE region for cooperation on transboundary aspects of climate change and on the development of adaptation strategies.

First and foremost, the Convention obliges Parties to prevent, control and reduce transboundary impacts including those related to adaptation to or mitigation of climate change.

Moreover the Parties shall take all appropriate measures to ensure that transboundary waters are used in a reasonable and equitable way. Thus the principles of reasonable and equitable use shall also be at the basis of any decision on adaptation measures within a transboundary basin.

The Convention also includes a number of obligations related to adaptation to climate change. It stipulates that joint water quality objectives shall be set and measures shall be designed to attain and maintain them. Parties are required to follow the precautionary principle which implies in the case of climate change taking action even before adverse impacts are fully proven scientifically. The Convention obliges Parties to exchange information about the current (and expected) conditions of transboundary waters as well as about the measures planned to prevent, control and reduce transboundary impact. The Convention also includes provisions for consultations, common research and development and joint monitoring and assessment; setting the basis for riparian countries to cooperate in the development of adaptation strategies. The Convention requires Parties to enter into bilateral or multilateral agreements and to establish institutions for cooperation and management of shared water resources, such as joint bodies which provide a good forum for transboundary adaptation. In addition, Parties are obliged to establish early warning systems, apply and exchange best available technology and mutually assist each other. Finally, Parties shall make information about the environmental status of transboundary waters, expected scenarios and water quality objectives available to the public.

The Water Convention has influenced the drafting of a number of bilateral and multilateral agreements on transboundary waters in the UNECE region. Proper implementation of the Convention thus provides a good basis for the execution of these sub-regional instruments, including work on adaptation (see boxes 4 and 5 on the Rhine and the Danube).

2.3.2 Protocol on Water and Health

The Protocol on Water and Health to the Water Convention aims to protect human health and well-being through improving water management and through preventing, controlling and reducing water-related disease. The primary target to be achieved by the Parties to the Protocol is access to drinking water and the provision of

Box 4: Towards an Adaptation Strategy in the Rhine[5] River Basin

The 1999 Rhine Convention, together with existing European Union (EU) and national legislation and policies and a strong political commitment in all countries in the Rhine catchment, provides a sound basis for developing and implementing an adaptation strategy on the impacts of climate change. Activities regarding adaptation to climate change have started with an assessment of the state of knowledge on climate change and its expected impact on the water regime in the Rhine, published in 2009. However, as long ago as in the 1990s, important measures were being taken regarding flood risk management, increasing the basin's adaptive capacity to respond to future expected climate changes.

Following the severe flooding in the Rhine in 1993 and 1995, the International Commission for the Protection of the Rhine (ICPR) developed and adopted a comprehensive "1998 Action Plan on Floods" covering the period until 2020. In the context of the implementation of the 1998 Flood Action Plan, the flood damage risk (defined as the product of damage potential (€) and the probability of flooding (per year) has been assessed. In addition, possibilities for reducing flood levels by implementing measures in the catchment area have been identified. The resulting information was published in the "Rhine Atlas 2001" as one of the elements aiming at increasing peoples' "flood awareness". The flood forecasting system has also been improved, in particular by improved cooperation between water management administrations and weather services.

The Action Plan aims at improving the protection of people and property against floods and at the same time at improving the floodplains of the Rhine. Great efforts have been made towards implementing the Action Plan and almost all measures due to be implemented by 2005 have in fact been undertaken. Their positive effect is demonstrable. In 2007, Rhine ministers confirmed the need to develop adaptation strategies for water management in order to be able to address the effects of climate change, which are clearly discernible.

The implementation of the 1998 Flood Action Plan over the period 1995–2005 was evaluated in 2007. The assessments will be repeated once every five years, the next time covering the period 1995–2010.

ADAPTATION STRATEGY FOR CLIMATE CHANGE IMPACTS

The ICPR has established a climate change expert group in spring 2008. The group has the mandate to discuss and evaluate climate change effects on the hydrological regime in the Rhine basin and in a second step to develop a basin-wide adaptation strategy. A cornerstone with regard to adaptation will be the ability to forecast possible impacts of climate change on the hydrology of the Rhine (flood levels and duration, low water levels and duration and water temperature). As a first step, an assessment of available information revealed changes in these parameters over the last 3–4 decades. A second step, the development of common scenarios for these parameters, will be finalized in 2010.

The eventual adaptation strategy will take account of experience gained with implementing the 1998 Flood Action Plan as well as the wider experience of the ICPR in protecting the Rhine. Synergies between flood protection and ecosystem and water quality improvements will be sought wherever possible, and problems, for e.g. drinking water supply and navigation due to low water levels, will also be addressed.

In this process, the ICPR has a coordinating and guiding role. The actual implementation of measures (including financing them) is the responsibility of the countries in the catchment area.

Source: ICPR secretariat. ICPR 2009. Analysis of the state of knowledge on climate changes so far and on the impact of climate change on the water regime in the Rhine watershed - Literature evaluation. Report 174. Available online at: http://www.iksr.org/index.php?id=128&L=3

sanitation for everyone within a framework of integrated water resource management aimed at the sustainable use of water, ambient water quality which does not endanger human health, and the protection of water-related ecosystems.

To meet these goals, Parties are required to establish national and local targets in a number of areas addressing the whole water and health nexus: from access to drinking water and sanitation, to quality of drinking water, bathing waters and quality of discharges, performance of water supply and waste-water treatment, health protection and good water management practices.

Climate change impacts should be taken into account when setting targets. In particular, access to safe drinking water and sanitation for everyone could be complicated by climate change.[6]

At the same time, the target-setting process by its own nature offers a useful tool for planning adaptation to climate change, as it requires the establishment of an intersectoral coordination mechanism, broad participation, and an analysis of gaps, development of scenarios and prioritization of measures based on development choices.[7]

Other provisions of the Protocol are also highly relevant to adaptation to climate change, in particular:

- The Protocol requires international cooperation to establish joint or coordinated systems for surveillance and early warning systems, contingency plans and response capacities, as well as mutual assistance to respond to outbreaks and incidents of water-related disease, especially those caused by extreme weather events;
- The Protocol also requires international support for national action, provided through the Ad Hoc Project Facilitation Mechanism, which is intended to help provide access to funding for activities to implement the Protocol.

[5] France, Germany, Luxemburg, the Netherlands, Switzerland, the European Community.
[6] For further guidance on this issue, refer to the Guidance on Water Supply and Sanitation in Extreme Weather Events, developed under the Protocol on Water and Health.
[7] For further guidance on this issue, refer to the Guidelines on the setting of targets, evaluation of progress and reporting, developed under the Protocol on Water and Health.

Box 5: Adaptation Under the Convention on Co-operation for the Protection and Sustainable Use of the River Danube (Danube River Protection Convention)[8]

The International Commission for the Protection of the Danube River (ICPDR) is a transnational body established in 1998 to implement the Danube River Protection Convention (DRPC).

The countries cooperating under the DRPC, including those outside the EU, agreed to implement the EU Water Framework Directive (EU WFD) throughout the entire Danube River Basin District and are preparing the Danube River Basin Management Plan and its Joint Programme of Measures, to be finalized by the end of 2009. The ICPDR became the platform for coordinating basin-wide WFD-related activities.

In preparation for the river basin management plan a Conference on the Adaptation of Water Management to the Effects of Climate Change in the Danube region took place in Vienna in December 2007. The goal was to discuss the expected effects of climate change on the water cycle, such as increased droughts and floods, and how the related challenges could be met. The conference conclusions were agreed at the Tenth Ordinary Meeting of the ICPDR in December 2007.

The conclusions from the Conference were:

- Climate change impacts:
  - Are an issue of Danube River basin-wide significance;
  - Will be addressed by a step-by-step approach;
  - Will be addressed while respecting all significant water management issues for the Danube River basin;
  - Issues of flood protection, low water discharges, drought and land use will be taken into account;
- Climate change signals for the Danube River basin are sufficient to justify acting despite existing scientific uncertainties;
- Ongoing Danube River basin scientific activities and their outcomes should be the basis for the further development of measures;
- Future infrastructure projects have to be "climate proof";
- River Basin Management approaches should be holistic and coherent (linking all relevant sectors)
- Provide flexible management tools and no regret measures.

NEXT STEPS

This first cycle of the river basin management planning process has led to the conclusion that climate change is a significant threat to the Danube River basin environment. The priority at this stage is to ensure that measures implemented to address key water management issues are "climate proof" or "no regret measures". Chapter 8 of the Danube River Basin Management (RBM) Plan on "Water Quantity Issues and Climate Change" includes the current state-of-play regarding knowledge on climate change in the Danube River basin, and possible current and future impacts on water resources as well as on water management. The second and subsequent cycles of the river basin planning process will ensure that climate issues are integrated within the RBM plan and will collect more evidence and provide greater precision over the potential impacts of climate change.

FUTURE ISSUES FOR THE DANUBE RIVER BASIN

The following challenges likely need to be addressed in subsequent cycles of the EU WFD:

- Ensuring that the monitoring systems used in the Danube River basin are able to detect climate change impacts on ecological and chemical water status.
- Investigating the effects of climate changes on eco-regions, typologies and reference sites as well as proposals for solutions.
- Improving climate and hydrological models at the Danube River basin scale.
- Improving scenarios for the Danube River basin.
- Investigating the effect of climate changes on the various sectors active in the Danube River basin and evaluating the associated indirect increases of impacts on water status.
- Enhancing sharing of research information on climate change.
- Ensuring that scientific information is "translated" to water managers.
- Improving presentation of information on climate fluctuations and ensuring that uncertainties are presented in a transparent way.
- Integration of the Danube RBM Plan and climate change threats in time for the second planning cycle.
- Identifying knowledge and information gaps as a priority for the ICPDR.

Source: ICPDR secretariat. Draft Danube River Basin Management Plan, Part A: Basin-wide overview, version 6.0, Date 18 May 2009.

[8] Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Montenegro, Romania, Republic of Moldova, Serbia, Slovakia, Slovenia, Ukraine and the European Community.

Box 6: Integrating Strategic Environmental Assessment (SEA) and Climate Change Adaptation in Policies, Plans and Strategies

SEA consists of a family of tools that identifies and addresses the environmental consequences and stakeholder concerns in the development of policies, plans and programmes. "The environment", depending on the scope of the SEA, ranges from the biophysical environment alone to encompass biophysical, social, economic and institutional environments. SEA aims at better strategies, ranging from legislation and countrywide development policies to more concrete sectoral and spatial plans. SEA assists in identifying, assessing and comparing the different ways in which a policy, plan or programme can achieve its objectives.

SEA is a legally embedded tool in the EU and in a growing number of countries worldwide, with clearly demarcated roles and responsibilities. Furthermore, there is a strong common understanding of what good SEA practice is. Transparency and stakeholder participation are core values in SEA that are supported by an increasing evidence base of good practices. SEA in itself however has relatively little content, but provides the procedural umbrella under which a variety of tools have to be used. However, SEA procedures can help in "climate-proofing" policies, plans and programmes.

For example, an SEA was conducted on the 2006–2010 hydropower development plan for the Vu Gia-Thu Bon River basin in Vietnam, taking into account climate change impacts. From the SEA it was concluded that the pace and scale of the proposed development was at an unsustainable level and a number of recommendations were made on the operational regimes and institutional arrangements to reduce droughts and floods and prepare for disasters; on the need to incorporate climate change parameters in design; and on the need for coordinated management and water release programs for the 60 dams under consideration.

SEA shares many characteristics with IWRM, like integration of environmental and social considerations into multi-sectoral decisions; participatory approaches; monitoring and evaluation of outcomes; broadening perspectives beyond immediate sectoral issues; and emphasis on the product as well as the process. SEA can therefore support water management while also taking into account climate change. Since climate change adaptation is a responsibility not only for the water sector but for various other linked sectors (tourism, agriculture, energy, etc.), SEA is a vehicle which can support implementing the principles of IWRM. As an (increasingly) legally established sector-neutral, broadly applied instrument, SEA can help to incorporate IWRM principles beyond water sector boundaries. For instance, SEA specifies requirements covering the practical implementation (process), like stakeholder participation and informed, transparent decision-making. IWRM on the other hand is more closely linked to the scientific dimension of climate change adaptation, thus providing comprehensive and integrated understanding of water sector issues to inform decision-making through SEA. There are consequently clear advantages to further elaboration of the added value of combining IWRM and SEA when working towards the implementation of climate change adaptation.

References: EU SEA directive 2001/42/EC

UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and Protocol on Strategic Environmental Assessment

OECD advisory note on strategic environmental assessment and climate change.

Co-operative programme on water and climate & Netherlands Commission for environmental assessment. 2009. IWRM and SEA joining forces for climate proofing. Online at: http://www.waterandclimate.org/UserFiles/File/PersPap%2016.%20IWRM%20and%20SEA.pdf

2.3.3 Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and Protocol on Strategic Environmental Assessment

The Espoo Convention supports environmentally sound and sustainable development by providing information on the inter-relationship between certain economic activities and their environmental consequences, in particular in a transboundary context.

The Convention specifies the procedural rights and duties of Parties with regard to transboundary impacts of proposed activities and provides procedures in a transboundary context for the consideration of environmental impacts in decision-making. The Convention stipulates that an EIA procedure be undertaken for an activity planned by one Party that is likely to have a significant transboundary impact in the territory of another Party. The Espoo Convention is therefore an important framework for ensuring that the adaptation strategies developed in a country do not cause transboundary impacts in neighbouring countries.

The Espoo Convention has been supplemented by a Protocol on Strategic Environmental Assessment (SEA), not yet in force. The Protocol will require its Parties to evaluate the environmental consequences of their official draft plans and programmes, and provides for extensive public participation in government decision-making in numerous development sectors. Like the Convention, the Protocol defines an environmental effect as meaning any impact on the environment, including human health, flora, fauna, biodiversity, soil, climate, air, water, landscape, natural sites, material assets, cultural heritage and the interaction among these factors.

SEA is undertaken much earlier in the decision-making process than project-level EIA, and it is therefore seen as a key tool supporting sustainable development. SEA can also be an effective tool for climate change adaptation and mitigation, by introducing climate change considerations into development planning (see also box 6).

2.3.4 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention)

The Aarhus Convention is unique among multilateral environmental agreements in the extent to which it promotes citizens' environmental rights. Its core principles – the right to information, the right to participate and the right to seek access to justice – empower ordinary members of the public both to play a greater role in promoting more sustainable forms of development and to hold Governments accountable.

Increasing access to information, public awareness and public participation in decision-making are foundations for the development and implementation of policies related to climate change issues. Focusing on these aims will be helpful in building the political commitment and capacity needed to understand and address the causes, impacts and approaches for mitigating climate change.

Article 6 of UNFCCC addresses education, public awareness, access to information, public participation and international cooperation. The work programme on Article 6 is guided inter alia by the promotion of partnerships, networks and synergies, in particular, synergies between Conventions. It encourages Parties to undertake activities under this article, including by developing national plans of action, targeting the specific needs of various actors and groups.

UNECE and the United Nations Institute for Training and Research (UNITAR) are exploring the possibility of elaborating, together with other partners, the assessment methodology to assist countries with their United Nations Framework Convention on Climate Change Article 6 commitments – in particular those related to public access to information and public participation in decision-making. This would be done within a national climate change governance framework.

2.4 Ramsar Convention on Wetlands

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention on Wetlands) provides a framework for national action and international cooperation for the conservation and wise use of wetlands, so to maintain their ecological character, i.e. the combination of the ecosystem components, processes and services. The Convention uses a broad definition of the types of wetlands covered in its scope, including swamps and marshes, lakes and rivers, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans.

The Convention requires Parties to: (a) work towards the wise use of all their wetlands through national land use planning, appropriate policies and legislation, management actions, and public education; (b) designate suitable wetlands for the List of Wetlands of International Importance ("Ramsar List") and ensure their effective management, and (c) cooperate internationally concerning transboundary wetlands, shared wetland systems, shared species and development projects that may affect wetlands.

At the Tenth Conference of the Parties in Changwon, Republic of Korea, in November 2008, a number of key resolutions were adopted addressing the strategic global issues of climate change (Resolution X.24), human health and well-being (Resolution X.23), biofuels (Resolution X.25), river basin management (Resolution X.19), extractive industries (Resolution X.26) with respect to wetlands.

2.5 International agreements relevant to coastal areas and oceans

The Regional Seas Programme aims to address the accelerating degradation of the world's oceans and coastal areas through the sustainable management and use of the marine and coastal environment. It stresses the need to integrate planning for transboundary river basins and for coastal waters, particularly for enclosed or shared seas, or where broad political arrangements are in place for regional seas. Relevant regional enclosed seas in the UNECE region where political arrangements are already in place include the Baltic, Black, Caspian, and Mediterranean Seas. Though they are not enclosed seas there are also relevant regional sea arrangements in place for the Arctic Ocean and the North-East Atlantic.

In November 2008, the Global Meeting of the Regional Seas Conventions and Action Plans adopted a statement on climate change that underlines the need for multidisciplinary efforts to adapt to, and mitigate the impacts of, climate change on coastal and marine ecosystems, and the services they provide to human well-being. The statement further underscores the importance of collaboration and coordination among international and regional organizations, governments, civil society and the private sector.

The Fourth Global Conference on Oceans, Coasts and Islands (Hanoi, 7–11 April 2008) underlined the fact that the climate change impacts, which ocean and coastal leaders around the world will need to face, will ineradicably change the nature of ocean and coastal management. This will introduce increased uncertainty and the need to incorporate climate change planning into all existing management processes, to develop and apply new tools related to vulnerability assessment, and to make difficult decisions involving adverse impacts to vulnerable ecosystems and communities.

2.6 The EU water-related legislation and approach to water and climate change

The **EU Water Framework Directive** establishes a framework for Community actions in the field of water policy to protect inland surface waters, transitional waters, coastal waters and groundwater. The Directive obliges Member States to assess the environmental pressures of human activities and their impact on waters, to set targets for improving the status of water bodies, implement the necessary measures and finally achieve "good status" for surface and ground water in 2015. Member States shall collect and maintain information on the type and magnitude of significant anthropogenic pressures to which the water bodies in each river basin district are liable. River basin management plans (RBMPs) containing concrete measures to be implemented have to be established with public participation and regularly reviewed (every six years) to take into account recent information. Within transboundary river basins, requirements for environmental objectives as well as programmes of measures should be coordinated for the basin as a whole. Guidance on how climate change shall be taken into account in the RBMPs is still under development within the Common Implementation Strategy (CIS) of the WFD and is expected to be finalized at the end of 2009.

The **EU Directive on the assessment and management of flood risks** (Floods Directive) establishes a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity. It entered into force in October 2007. Member States shall, for each river basin district, or unit of management or portion of an international river basin district lying within their territory, undertake a preliminary flood risk assessment. Flood hazard and flood risk maps then have to be created at the most appropriate scale, and, on the basis of these maps, flood risk management plans coordinated at the level of the river basin district have to be established. Concrete measures to reduce flood risks should, as far as possible, be coordinated for the river basin as a whole, in particular for transboundary basins. These three steps are planned to be reviewed every six years. Therefore, Member States shall ensure that exchanges of relevant information and data take place between their competent authorities from the outset. National legislation should be adjusted to the Floods Directive and be able to fulfil in particular its requirements at the national level as a basis for doing so at the transboundary level. Since climate change contributes to an increase in the likelihood and adverse impact of flood events the expected impact of climate change on the occurrence of floods shall be taken into account within all required stages of implementing this directive.

The EU, having focused for a number of years mainly on climate change mitigation, has progressively recognized the need for climate adaptation. In June 2007, the European Commission presented a discussion paper known as the **Green Paper on adapting to the impacts of climate change**. The paper builds upon the work and findings of the European Climate Change Programme. It describes possible avenues for action at EU level. A broad public debate including stakeholder consultations took place on the Green Paper during 2007–2008. This led to work on a follow-up policy paper known as the White Paper.

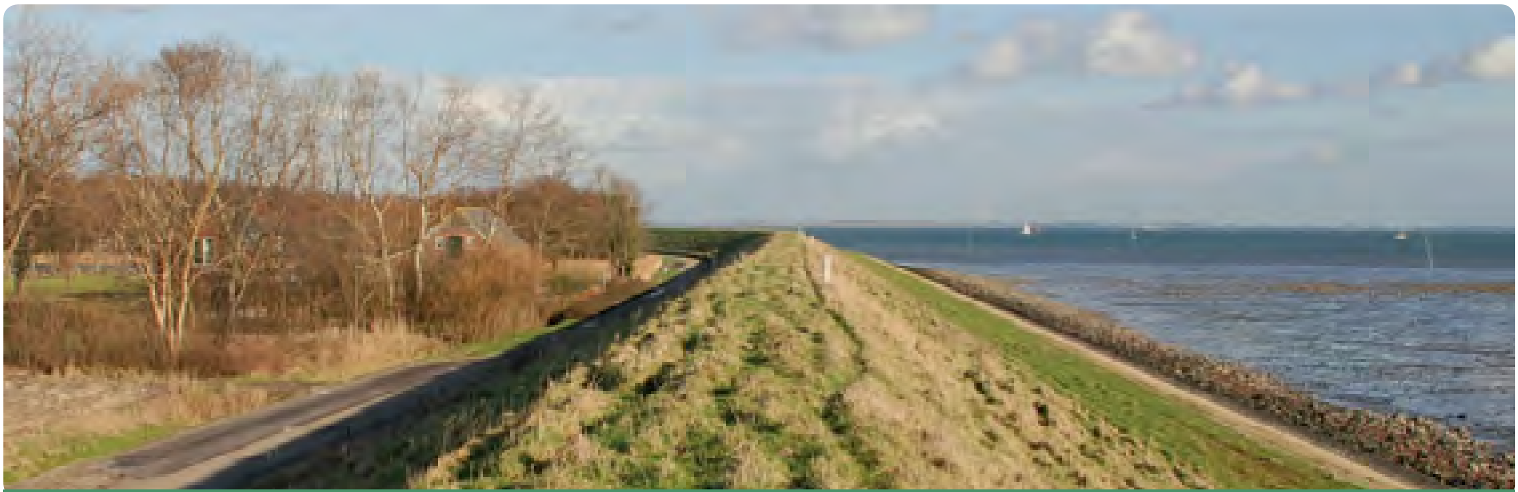
The Commission published the **White Paper "Adapting to climate change: Towards a European framework for action"** in April 2009 (see also box 7). The White Paper presents a framework within which the EU and its Member States can prepare for the impacts of climate change. The framework will evolve as further evidence becomes available. It will complement actions by Member States and support wider international efforts to adapt to climate change.

The White Paper is accompanied by an Impact Assessment which focuses on economic, environmental and social impacts in various key sectors (e.g. agriculture, forests, fisheries, energy, infrastructure/building, industry/services, tourism and health) and cross-cutting issues (water, ecosystems/biodiversity and land use). In order to take decisions on adaptation measures access to reliable data on the likely impact of climate change and associated socio-economic aspects as well as the costs and benefits of different adaptation options is needed. The knowledge generated on adaptation should also be made available to other countries, in particular developing countries.

The European Commission elaborated a **Communication on water scarcity and droughts**, which is closely linked to climate change and adaptation. An underlying technical report provides recommendations on how to develop drought plans with mitigation and prevention measures in order to minimise the environmental, economic and social damage caused by droughts.

The EU has significant coastal resources, the management of which is complex due to the different issues and interests at play in the coastal zone. The European Parliament and the Council have adopted a Recommendation inviting Member States to implement an integrated participatory territorial approach to the planning and management of the coastal zone on the basis of common principles. The Commission provides guidance and supports the implementation of ICZM by Member States at the local, regional and national levels.

The marine strategy was codified in Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (**Marine Strategy Framework Directive**). The Directive recognizes that flexibility is needed in the protection and management of the marine environment in view of the evolution of the impact of climate change. It recognizes in particular the need to address the special vulnerability of the Arctic region to climate change impacts. The Directive describes marine strategies, the establishment of environmental targets, monitoring and measures. Member States shall use relevant international forums, including mechanisms and structures of regional sea conventions, to coordinate their actions with third countries having sovereignty or jurisdiction over waters in the same marine region or subregion.



Box 7: The EU White Paper – Adapting to Climate Change: Towards a European Framework for Action

BASIC FACTS:

Adaptation to climate change impacts is needed

Impacts are often uncertain and different scenarios exist

Impacts differ per region and per sector/social group

Early action will bring economic, environmental and social benefits

Action at EU level is needed to guarantee cohesion, to address transboundary impacts and to adjust existing EU policies

AIM:

Identify EU level actions to co-ordinate and strengthen national, regional and local action on adaptation to climate change

METHOD:

Cooperation in partnership – solidarity and subsidiarity

ONE OF THE KEY SECTORS IS WATER

- The existing EU water related legislation (Water Framework Directive, Floods Directive, Marine Strategy Directive etc.) can facilitate adaptation by ensuring that climate change considerations are incorporated and by providing mechanism for regular updating to take account of new information.
- Examples of actions:
  - Make river basin management plans climate proof
  - Prevent and reduce water scarcity
  - Increase water efficiency
  - Increase water storage capacity of ecosystems
  - Embed water management in rural development strategies

The White Paper establishes a framework for action focusing on four key pillars:

- **Building a stronger knowledge base**: Information availability differs considerably across regions; European-wide monitoring programmes and spatially detailed information including climate change impact scenarios are lacking. A better understanding of the socio-economic aspects, the costs and benefits of different adaptation options and information on good practices are also required. To improve knowledge management it is planned to establish a clearing house mechanism as an information technology tool and database on climate change impact, vulnerability and best practices on adaptation. This mechanism will rely on geographical information provided by the Global Monitoring for Environment and Security (GMES) and will contribute to the Shared Environmental Information System (a collaboration by the European Commission and the European Environment Agency (EEA) to establish an integrated and shared EU-wide environmental information system with the Member States).
- **Taking climate change impacts into consideration in key EU policies:** A number of sectors with strong EU policy involvement need to consider climate risk and adaptation measures. Mainstreaming of adaptation into sectoral policies at European level is important to reduce, in the long-term, the vulnerability of sectors such as: agriculture, forests, biodiversity, fisheries, energy, transport, water and health. Mainstreaming adaptation means integrating further climate risks into relevant policy interventions.
- **Financing – combining different policy measures to the best effect:** Climate change is one of the priorities for the EU's current multi-annual financial framework (2007–2013) and it is important to ensure that the available funds are used to reflect this priority. In addition, optimising the use of insurance and other financial services products could also be explored. Consideration should be given to the role of specialized market-based instruments. The possibility of using revenue generated from auctioning allowances under the Community greenhouse gas emission allowance trading system (the EU ETS) for adaptation purposes should be utilised.
- **Supporting wider international efforts on adaptation:** EU external cooperation should make a significant contribution to promoting adaptation in partner countries; particularly neighbouring countries. Bilateral and regional financial assistance programmes will aim to integrate adaptation considerations into all relevant sectors.

The EU framework adopts a phased approach. The intention is that phase 1 (2009–2012) will take forward the work identified under the four pillars. This leads to the elaboration of a comprehensive adaptation strategy for the EU which will be implemented during phase 2 commencing in 2012.

Source: EC DG Environment http://ec.europa.eu/environment/climat/adaptation/index_en.htm

Chapter 3

Policy, Legislation and Institutional Frameworks

Policy should create an enabling environment for adaptation to climate change through, among other things, climate-proofing of policy, and legal and institutional frameworks, and by strong communication.

Any policy should be based on the understanding that stable and unchanging baseline conditions no longer exist.

Climate change adaptation should be integrated into existing policy developments. This integration can also enhance coherence among policy sectors and avoid potential conflicts.

Spatial planning is an important basis on which to develop policies that take into account all sectors.

Policy development should be based on the principles of multi-level governance.

Legislation should be developed in a flexible way and should not present barriers for adaptation. Transboundary agreements should include provisions for flow variability.

The roles and responsibilities of institutions dealing with climate change adaptation should be clearly defined.

A dedicated research team should be established to improve understanding of the implications of climate change for water resources and their management.

Joint bodies should have the mandate, capacity and means to ensure they can execute their responsibilities in developing and coordinating adaptation strategies for transboundary basins.

Proper education, capacity-building and communication are imperative for climate change adaptation.

This chapter aims to help decision-makers to introduce and adopt policy, legislation and institutional frameworks that support adaptation to climate change at the national level as well as in a transboundary context.

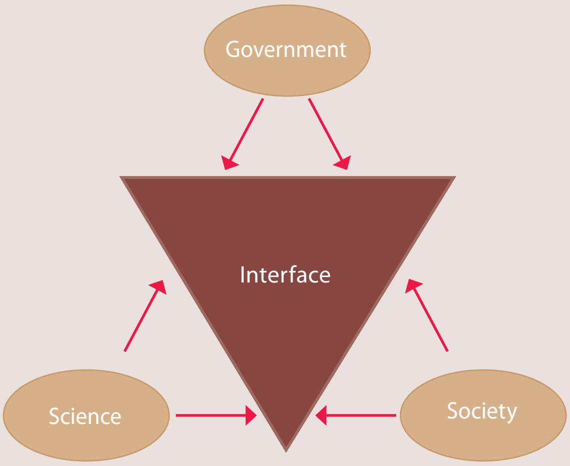
Policy, legislation and institutional frameworks, both at the national and transboundary levels, should together support adaptation to climate change. Conditions for successful adaptation strategies include willingness to cooperate among actors, a strong political commitment at the transboundary and national level, agreed targets, sound science, public participation and effective processes which ensure that policy, legal and institutional developments reflect science.

3.1 Policy adaptation

The most essential and challenging task for policymakers is to create an enabling environment for adaptation to climate change on all levels. As climate change imposes a new reality, the political, legal and institutional frameworks need to be assessed and adjusted to allow for climate change adaptation. At the same time, it has to be ensured that existing policies are implemented and legal frameworks are enforced.

Many policies in the field of, for instance, land use planning, environmental protection and health management have long sought to manage the risks associated with shorter-term, seasonal to inter-annual climatic variability, e.g. extreme weather events, floods, and droughts which are determined by climatic and environmental conditions which are stable and unchanging in the long term. Sound and sustainable policies at the local, national and transboundary levels should however acknowledge the new conditions where the baseline is inherently unstable and changing. An appropriate response therefore needs to be developed to increase the resistance and resilience of the policies that will be directly or indirectly affected by the impacts of climate change, also referred to as climate-proofing.

Box 8: The Trialogue Model



Schematic representation of the Trialogue Model

The Trialogue Model assumes that the success of governance depends on the balance between Government, Science and Society; the three elements in the model. Government is in essence what is known as the *trias politicas* the making of rules, the application of rules, and the adjudication of rules. Society represents the collective interests of people, encompassing the societal, economic and ecological values of people where the sustainable development discourse takes place. Science, finally, represents the organized and systematic gathering and dissemination of knowledge relevant to the decision-making process.

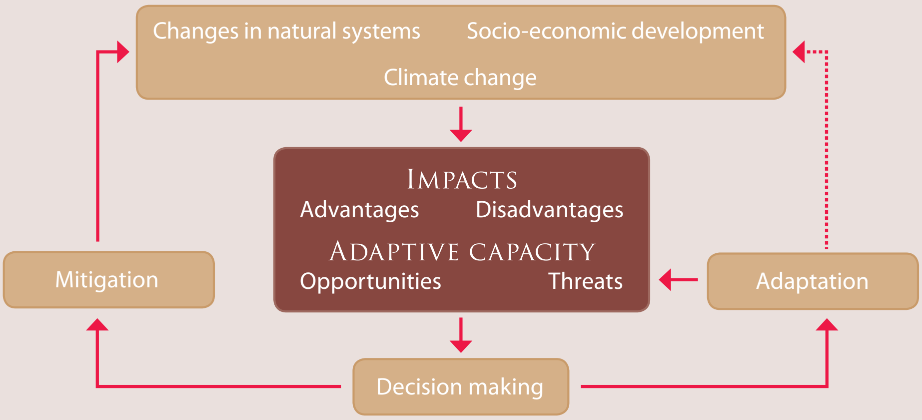
Governance requires effective interfaces between (a) Society and Science, (b) Government and Society, and (c) Government and Science. The quality of the interfaces determines the extent to which government can generate the incentives needed to develop society by allowing science to inform the decision-making process. The Society-Science interface entails science in the service of society, including the diffusion of scientific knowledge into society. The Government-Society interface determines the needs and requirements of society, the legitimacy of the political process, and the permeability of government to new ideas from civil society. The interface also represents the degree to which the needs of society are satisfied by government. The Government-Science interface determines the extent to which scientific knowledge forms the basis for decision-making as well as the extent to which government facilitates and enables the scientific process.

In essence, good governance promotes participatory water resource management. This requires a good understanding of the institutional structures that enable a government to function effectively. There is therefore a need for cooperation between Government and Society to find a viable solution that is agreeable to both parties. This solution should be sustained by scientific support.

The Trialogue Model recognizes that adaptation not only involves governments, but also takes place through everyday actions and networks at the community and household levels and with the involvement of the scientific community. By assessing potential roles that can be played by the three groups, decision makers are provided with a wider range of management options. By recognizing the importance of making decisions that incorporate and weigh multiple actors and concerns, the Trialogue Model is a requisite for effective transboundary water management and cooperation.

Source: Turton, A. R. et al. (eds.), 2007. Governance as a Trialogue: Government-Society-Science in Transition. Berlin, Springer-Verlag.

Box 9: Developing the National Climate Change Strategy in Finland – A Trialogue



Framework of Finland's National Strategy for Adaptation to Climate Change

The Finnish Government in 2001 identified the need to draft a programme for adaptation to climate change. The preparation of the national adaptation strategy started in autumn 2003 and was finished in January 2005. The process took place in the form of a trialogue. The Government initiated and guided the process. Scientists were at the same time able to receive funding for several climate change-related projects from the Environmental Cluster Research Programme in 2003–2005, so they were also able to support policymakers. Society at all levels, citizens as well as stakeholders, had an opportunity to comment on the widely circulated adaptation strategy in a public hearing and also on the Internet.

The national strategy work was coordinated by the Ministry of Agriculture and Forestry, while there were representatives from several other ministries, the Finnish Meteorological Institute and the Finnish Environment Institute. The strategy work used as its reference a set of existing scenarios of future Finnish climate and the Government Institute for Economic Research prepared long-term economic scenarios.

The largest research project assessed the adaptive capacity of the Finnish environment and society under a changing climate. The project included a range of experts and researchers from eleven partner institutions covering among other topics climate data and scenarios, biological diversity, water resources and human health.

Currently the national strategy is in the process of being implemented primarily through sector-specific programmes. In addition, a five-year research programme for 2006–2010 has been launched to address the need to strengthen policy-relevant research and development questions.

Source: Finnish Environment Institute
www.ymparisto.fi

Climate change adaptation should be integrated in the development of planning, programmes and budgeting across a broad range of economic sectors, through mainstreaming and the establishment of effective and stable adaptation policy frameworks. Such a coordinated, integrated approach to adaptation is needed to address the scale, complexity and urgency of addressing climate change impacts. Governments should ensure that all existing policies are in line with the requirements for adaptation to climate change and that existing sectoral polices do not conflict with and hamper adaptation in other sectors. This integration can also promote coherence among policy sectors and prevent policies working at cross-purposes.

The involvement of a broad range of sectors is needed to create and share a common understanding. Sectors also need to reach out to each other: e.g. the health sector needs to sensitize the water sector on health risks and the coastal and the marine sector need to be integrated with the water sector. Spatial planning links vulnerability and risk assessment with adaptive capacities and adaptation responses in water management, like prevention of building settlements in flood-prone areas. It is therefore the pre-eminent policy sector to facilitate the identification of policy options and cost-efficient strategies that target all sectors.

The need for adaptation is not only a burden but can also be an opportunity for innovation and new technologies. This should be explored in close cooperation with the public and private sectors.

Transboundary rivers, lakes and groundwaters pose particular management challenges because of potentially competing national interests. Adaptation therefore requires transboundary cooperation, based on river basins and bio-geographic regions. While most measures will have to be implemented at the national or local level, where operational capacities exist, it is essential that efforts be coordinated in an equitable, acceptable and cost-effective manner at the level of the transboundary basin.

Freshwater, coast and ocean systems are closely inter-linked and must be managed together. Coastal conditions are strongly dependent on

Box 10: Involving Society: The HarmoniCOP Project

Public participation is a generally accepted approach in water management, but implementing it is still difficult. The EU-financed project “Harmonizing Collaborative Planning” (HarmoniCOP) was specifically designed to help increase practitioners' understanding of participatory river basin management planning in Europe. Experience from this project shows that the single most important problem is the lack of clarity about the role of stakeholder involvement. Stakeholders often doubted that their input would make a difference, which is critical for motivating people to participate. Apart from this, the existing governance style was often not participatory, and it took a lot of effort to move towards a more collaborative approach. In many cases the authorities lacked experience with multi-party approaches, relied heavily on technical expertise, were not willing to change, feared to lose control or feared that too broad participation could threaten the confidentiality of proceedings. Consequently participation often remained limited to information provision or consultation.

Other difficulties included limited resources for organising participatory processes and also for participating in these processes. This can also result in unrepresentative participation. Typically, stakeholder groups and individuals with greater resources (information, money, time, skills, etc.) are over-represented and can exert more influence. Unless underprivileged stakeholders are actively supported, public participation may actually reinforce power imbalances rather than reduce them. Finally, some cases took technical models as their starting point instead of the issues as seen by the stakeholders. In some cases overly technical language and overly complex information and communication tools were used, with little attention to communication and interaction between the stakeholders.

In many cases implementing public participation requires political, institutional and cultural change. Sometimes opportunities for truly participatory approaches may arise at the local level or in specific policy processes - an influential politician may for instance favour public participation, or there is a public controversy that cannot be resolved without involving the public. Provided these processes are well organised, they increase positive experiences with and support for public participation.

In several cases relations between different stakeholders improved. In most cases many stakeholders got a better understanding of the management issues at stake and got to know and appreciate each other's perspectives. This opened up possibilities for win-win solutions and solutions that the authorities had not previously considered. In several cases the participatory process resulted in clearly identifiable improvements for the stakeholders and for the environment. In some cases a new basin-wide public organization was established.

Important preconditions for public participation are to clearly define the aims and ambitions of water managers and authorities and the ways that the output of the participatory process will be incorporated into management and policy processes. While participatory methods may succeed in providing the informed views of a selection of citizens, and in producing recommendations that can contribute to the quality of the decision-making, the process has to also allow the views and interests of these groups to be included in the decision-making and policy processes that determine the scope and outcomes of water management.

References: Gooch, G.D. and D.Huitema, 2008. Participation in water management: Theory and practice. Chapter 3 in Timmerman, J.G., C. Pahl-Wostl, and J. Möltgen, (eds.) 2008. *The adaptiveness of IWRM: Analysing European research.* London, IWA publishing.

Ridder, D., E. Mostert, and H.A. Wolters, 2005. *Learning together to manage together – Improving participation in water management.* Osnabrück, Germany, University of Osnabrück, http://www.harmonicop.info/HarmoniCOPHandbook.pdf.

Website: http://www.harmonicop.info

flows from the river basins, which affect the functioning of important coastal and ocean ecosystems, ocean productivity and ocean circulation patterns. The river system in turn is strongly affected by tides, surges and salinity intrusion from the coast. The two meet in the transitional waters such as estuaries and deltas. Climate change, affecting both freshwater and marine systems, is an added challenge and calls for urgency in addressing these linkages.

3.2. Governance

Policymakers should aim to establish effective communication on multiple levels involving all actors like individual citizens, local authorities, stakeholders from relevant sectors and policymakers at the international level. The different levels should support each other, for example through the establishment of consultative mechanisms at both the national and transboundary levels.

A participatory approach is also recommended to develop scenarios, impact assessments and adaptation strategies and measures. The Trialogue Model, for example, describes the basic actors in good governance: government, science and society. It can be used as the basis for successful adaptation measures (boxes 8 and 9).

To foster cooperation on adaptation between different levels and across borders, the following principles of good governance should be applied:

- Accountability: providing access to justice in environmental matters;
- Transparency: providing access to information;
- Participation: enabling participation by all stakeholders (see also box 10).

These principles include an integrated approach whereby environmental and health concerns can be incorporated into all decisions, where decisions are made at the appropriate level.

3.3 Assessing and improving legislation for adaptation

Existing legislation can present barriers to future adaptation. So, as a first step, from the local to the transboundary level, it should be assessed in terms of its capacity to support adaptation to climate change, taking into account the principles of chapter 1. If necessary it should be reformed. Legislation should be flexible enough to accommodate ongoing environmental and socio-economic changes, and capable of adapting to future changes. For instance, increasing water stress is expected to lead to an increased use of new water sources such as wastewater, excreta and grey water in agriculture and aquaculture; the regulatory framework and its enforcement for health protection should be prepared to adapt.

Since the effects of climate change remain uncertain, legal frameworks, especially those including water allocation, should be flexible enough to respond to any projected or unforeseen change. Flexibility can imply an ability to change the rules, for example in order to introduce new knowledge, or an option to apply a variety of policies to face climate change. The following includes possible options which can be used to make transboundary agreements "climate-proof"; however, their selection will depend on the national and transboundary circumstances and the agreement of all riparian countries:

- Transboundary waters agreements or the regulations to implement them should address large variations in water availability and how to handle them. For instance, specifying water allocations to be delivered from upstream to downstream countries in percentage figures compared to the overall flow rather than in total numbers could permit more flexible reaction to flow variability as a consequence of climate change. In addition, when negotiating transboundary agreements, countries should not only take into account optimistic water availability scenarios, but also hydrological extremes (see box 11);

- Including special provisions addressing temporal and spatial redistribution of water resources in transboundary water agreements is recommended. Agreements with specific water allocations, for instance, may give the upstream country the possibility of delivering less water than foreseen in the treaty (but at least a specified minimum amount), during a limited period of time and with an acceptable justification, such as a severe drought period. This can be balanced by a compensation mechanism, i.e. the upstream country should deliver more water in the following period. Or it could be combined with accompanying mechanisms such as a prioritization of water uses for drought cases. The agreement should clearly specify the conditions for invoking the provision and require consultations between the riparian countries for such cases;

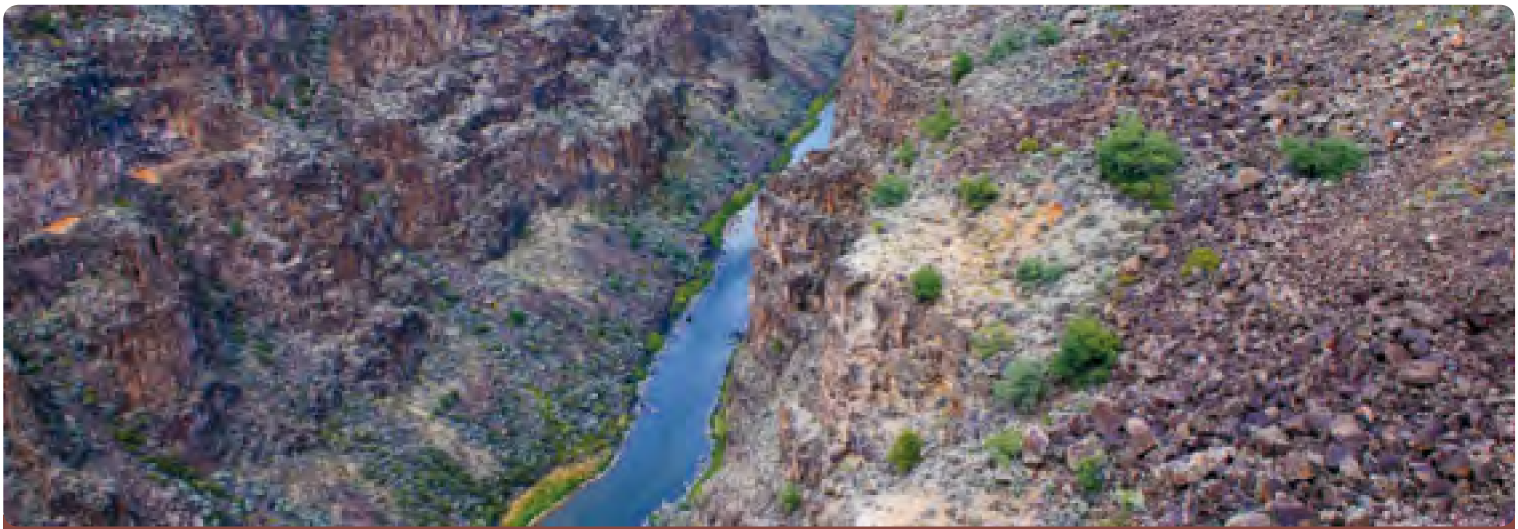
- Another option for flexibility is the inclusion of periodic reviews of water allocations. Such reviews and possible adjustments should be supported by seasonal forecasts that take account of climate change. This can on the one hand complicate the agreement application and possibly have high political costs, but it should prevent non-compliance caused by changes in resource conditions;

- Developing formalized communication between Parties through, for example, joint bodies provides a means for solving possible water conflicts and for negotiating water allocations in the face of changing climatic conditions, thus removing the need to rely entirely on inflexible rules on resource sharing. Obligations to notify and consult in cases of reduced water availability should be included in the agreement, as required by the Water Convention. So joint bodies with a wide scope, competence and jurisdiction are very important for making transboundary agreements "climate proof". Conflict resolution mechanisms such as compulsory fact-finding, conciliation, negotiation, inquiry or arbitration can provide a means to solve conflicts between concerned parties;

- In some cases broadening the scope of cooperation beyond water allows concessions to be made by each party on some issues in exchange for gains on matters they perceive to be of similar importance. For example, concurrent discussion on several related issues such as water and energy or food exchange can allow trade-offs on several issues.

All these mechanisms have advantages, but also involve political and other costs, and so they should be chosen according to local conditions. Combining different approaches also depends on individual circumstances (box 11).

It is essential that national implementation is consistent with the obligations set out in transboundary agreements and regional legislation. This demands clear and rigorous compliance reporting and enforcement mechanisms.



Box 11: Examples of Legal and Institutional Arrangements for Transboundary Cooperation Addressing Flow Variability

Some mechanisms that allow flexibility in treaty implementation and thus encourage cooperation on changes in resource availability have already been applied with varying degrees of success. This depends on different factors such as political will, correct projections of future water availability, accompanying mechanisms such as consultations, and also on external political conditions.

SPECIAL PROVISIONS AND REVISION OF AGREEMENT

The Convention on Cooperation for the Protection and Sustainable Use of the Waters of Portuguese-Spanish River Basins and its Additional Protocol defines, for each river basin, the amount of water that should be received by the downstream riparian state and river boundaries control sections.

This flow regime is basically subject to the precipitation conditions in the Spanish part of the basins, but also in the case of the Tejo river in the Portuguese part of the basin, and in the case of the Guadiana river to the water storage conditions in six Spanish reservoirs. When the precipitation in a basin becomes extremely low and falls bellow certain thresholds, the defined flow regime might not apply, but during these exceptional periods the water should be managed in such a way as to ensure its priority uses.

So far, the annual flow regime has been operating well and, at the same time, a good collaboration atmosphere between the parties allowed them to overcome difficult situations, such as water shortages in an exceptional drought period, 2004-2005, recorded in the Douro, Tejo and Guadiana basins. In addition, the parties agreed on a provisional flow regime, in order to reduce drought effects on the Portuguese river basins.

In February 2008, the bilateral Convention was amended to establish a new annual flow regime. This new regime determines a quarterly (Minho, Douro, Tejo and Guadiana), weekly (Douro and Tejo) and daily (Guadiana) discharge flow, depending on the rainfall conditions in each basin. This agreement became effective on August 5, 2009.

SPECIAL PROVISIONS AND PERIODIC REVIEW

The treaty between Mexico and the United States regarding the allocation of the waters of the Colorado River and Rio Grande includes two provisions that take extraordinary drought into consideration. In the event of an extraordinary drought that makes it difficult for Mexico to deliver its assigned volume of Rio Grande water to the United States, any deficiencies existing at the end of one five-year cycle should be made up in the following cycle. If an extraordinary drought makes it difficult for the United States to deliver the guaranteed volume of Colorado River water to Mexico, the allocation of Mexico will be reduced in the same proportion as consumptive uses in the United States are reduced. Furthermore, the treaty includes an order of preference for specific uses of water shared between the two sides that can facilitate the process of determining an equitable utilization in the event of climate-related flow alteration.

However, in the 1990s Mexico was not able to cover the deficit in waters owed to the United States as specified in the treaty due to a prolonged drought of more than five years. The following measures were taken: Mexico entered into several agreements and understandings under which it guaranteed the delivery of certain volumes of water to partially cover its outstanding deficit in waters owed to the United States and funding was provided through the North American Development Bank to improve Mexico's irrigation system along the Rio Grande and thus enhance its ability to meet its treaty obligations to the United States.

In March 2005, with the announcement that Mexico would pay its debt, the United States and Mexico announced a joint intent not only to formalize procedures for operations under drought, but to "meet annually to review basin conditions, develop firm water delivery plans for the next cycle year, and work cooperatively on drought management strategies that can benefit both countries". Mexico repaid its accumulated water debt in 2005 and has accrued none since then.

BROADENING THE SCOPE OF COOPERATION

The 1998 Agreement between the Governments of the Republic of Kazakhstan, the Republic of Kyrgyzstan, the Republic of Tajikistan and the Republic of Uzbekistan on the Use of Water and Energy Resources of the Syr Darya basin links water deliveries with non-hydro energy supplies such as coal, gas and fuel oil as well as with the "rendering of other types of products". So if the basin suffers low river flows in one year, the countries can agree on a water-hydro-carbon energy exchange to save water for irrigation in the growing season (e.g. in Kazakhstan) which otherwise would have been released in the winter-time for hydro-energy production (e.g. in Kyrgyzstan). This mechanism could theoretically enable the states to adapt to changes in water availability. However, the actual implementation has been problematic.

References: Fischhendler, I., 2004. Legal and institutional adaptation to climate uncertainty: a study of international rivers. *Water Policy* 6: 281–302.

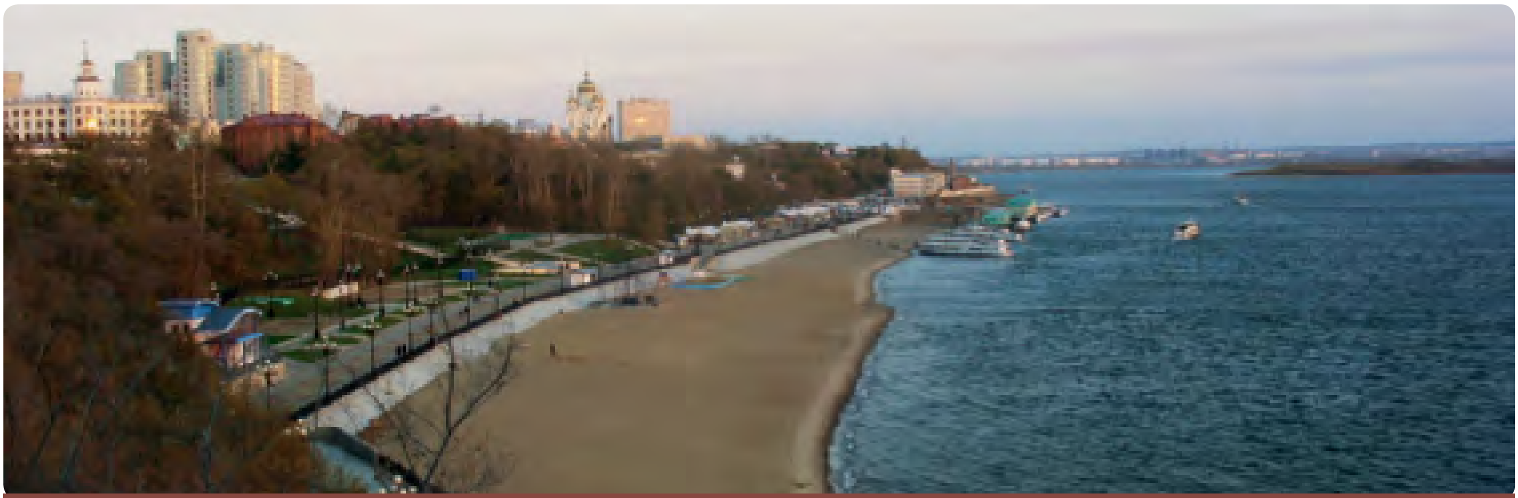
Drieschova, A., M. Giordano and I. Fischhendler, 2008. Governance Mechanisms to Address Flow Variability in Water Treaties. *Global Environmental Change 18 (2)*: 285–295.

Fischhendler, I., D. Eaton and E. Feitelson, 2004. *The Short and Long Term Ramifications of Linkages Involving Natural Resources: The U.S.-Mexico Transboundary Water Case.* Environment and Planning C, 22 (5): 633–650.

United States Department of State.

Ministry of the Environment, and Rural and Marine Affairs, Spain

Water Institute, Portugal



Box 12: Transboundary Cooperation: The Amur River Basin

The Amur River catchment area is located within three states – the Russian Federation (995 km², about 54 per cent of the basin), China (820 km², 44.2 per cent) and Mongolia (33 km², 1.8 per cent). A major part of the river forms the border between the Russian Federation and China. The water level in the Amur River shows considerable fluctuations, caused almost exclusively by the monsoon rains which constitute up to 75 per cent of the annual precipitation. The riparian countries, as in the case of any transboundary river, are equally interested in good ecological conditions and water quality meeting sanitary and ecological requirements. The Chinese part of the catchment area has a large population and development is progressing quickly. The Russian part of the basin is less populated. Pressures on the basin include the dumping of polluting substances, disregarding water security zones in areas with intensive human activity, river modifications that change the position of the riverbed and processes, and complex hydraulic engineering that changes drainage characteristics. All this causes the degradation of transboundary ecosystems in a considerable part of the Amur catchment.

The Intergovernmental Agreement on Rational Use and Protection of Transboundary Waters has been signed by the Russian Federation and China. Its purpose is to reduce the pollution of the rivers and lakes and maintain the ecological safety. Signing the Agreement reflects the readiness of the Parties to develop a complex legal agreement to protect nature from water pollution. In the agreement, the main principles of cooperation in the field of sharing and protection of transboundary waters as contained in the Water Convention are reflected:

- Elaboration of uniform specifications and quality standards of transboundary waters;
- Assistance in the application of modern technologies for the rational use and protection of transboundary waters;
- Information exchange on plans and actions that may lead to significant transboundary effects, in order to prevent such effects;
- Proper maintenance of the technical condition of existing hydraulic engineering and other structures;
- Completing actions for river channel stabilization and prevention of erosion;
- Monitoring of transboundary waters and exchange of the data derived;
- Holding of joint research activities, cooperation in the sphere of hydrology, and the prevention of floods on transboundary waters

Various departments and scientific organizations have assessed the dangerous hydrological phenomena of the Amur River basin. In future, the average water level is expected to continue increasing and techniques are being developed to estimate the damage for some settlements under current conditions and under conditions of expected increased river discharge. Sites where the channel is expected to become unstable are being identified and studied, and engineering methods to protect the territory undertaken. On large inflows to the river, big reservoirs are being constructed. Besides hydropower production, they also function as flow regulators.

To date, opinion on the hydrological consequences of climate change in the Far East remains divided. Modelling the results of the changes in annual run-off in the Amur basin do not show major changes; according to the Institute of Water Problems of the Russian Academy of Sciences, the projected reduction in annual run-off does not exceed its mean deviation. However, the State Hydrophysical Observatory calculated a significant increase in annual run-off based on the newest IPCC models and under scenario A2. Despite this contradiction, the signed agreement guarantees a joint assessment of the situation and further bilateral study of the hydrological processes of the basin, as decided at the first meeting of the joint Russian-Chinese commission on rational use and protection of the transboundary waters, from 26 to 28 December 2008 in Khabarovsk.

Source: Official website of Russian Federal Water Resources Agency (www.voda.mnr.gov.ru).

3.4 Institutional aspects

Institutional capacity from the local to the transboundary level is crucial in implementing effective adaptation. A very clear definition of the roles and responsibilities of each authority is essential, in particular in the case of extreme events. To this end, decision-making, communication protocols and contingency planning should be very clear and training and simulations exercises should be carried out on a regular basis. This should be supported by climate and hydrological information systems, capable of delivering early warnings in a timely and efficient manner.

Existing institutional gaps should be identified through in-depth gap analysis that includes all steps of adaptation. Gaps should be addressed in the national adaptation strategy.

All relevant authorities, including local authorities responsible for water management, should be involved in the development of the adaptation strategy. This is particularly important for federal States. A country-specific inter-ministerial committee engaging key stakeholders and ministries such as the ministry of environment, water, health, transport, agriculture, finance, interior, etc. should be established, as well as, if necessary, a high-level steering committee, with transboundary competence.

Box 13: United States Environmental Protection Agency National Water Programme Strategy: Response to Climate Change

In September 2008, the United States Environmental Protection Agency released the National Water Programme Strategy: Response to Climate Change, which provides an overview of the potential effects of climate change on water resources and the nation's clean water and safe drinking water programs and describes specific actions the National Water Programme will take to adapt programme implementation in light of climate change. The strategy includes five key areas to which a variety of actions are being undertaken:

WATER PROGRAMME MITIGATION OF GREENHOUSE GASES

The National Water Programme will expand existing programs that result in greenhouse gas mitigation and expand efforts related to geologic and biological sequestration of carbon dioxide. Examples of actions:

- Improving energy efficiency in drinking water and wastewater treatment facilities, and promoting on-site energy generation by recovering biogas from wastewater treatment facilities;
- Promoting water conservation which saves energy used for pumping, cleaning and heating water: e.g. label water efficient products; improve water conveyance leak detection and remediation; promote industrial water conservation, water reuse and recycling;
- Evaluating and encouraging water-related "biological" sequestration of carbon, e.g. wetlands or riparian buffers.

WATER PROGRAMME ADAPTATION TO CLIMATE CHANGE

The National Water Programme will implement a range of actions to tailor existing water programs to the challenges posed by climate change. This is done by measuring, minimizing and managing the impacts of climate change on water resources using effective adaptation approaches; by being proactive in adapting watershed protection, wetlands, and infrastructure programmes; by developing tools, standards and guidelines, and best practices to understand and measure the nature and magnitude of chemical, biological, and physical effects of climate change on water resources; and by applying environmental science, technology, and information to guide and support proactive climate change planning and management. Examples of action:

- Addressing impacts of climate change on potential contamination of drinking water sources;
- Assessing need for new or revised clean water microbial criteria to protect water quality;
- Promoting the "Climate Ready Estuaries" Programme;
- Developing a climate assessment tool (CAT) element of the BASINS watershed modelling programme;
- Reviewing and revising non-point pollution management measures.

CLIMATE CHANGE RESEARCH RELATED TO WATER

The National Water Programme will identify and complement climate research by others that support water programmes and this strategy. The National Water Programme will expand participation in inter-agency and intra-agency research planning related to climate change and will adjust core water program research to climate issues as needed.

WATER PROGRAMME EDUCATION ON CLIMATE CHANGE

The National Water Programme will invest in climate change education on water issues for water program managers and partners, will support sharing of information about State and local responses to water impacts of climate change, and will provide tools and technical assistance to support this effort.

WATER PROGRAMME MANAGEMENT OF CLIMATE CHANGE

The National Water Programme will maintain a Climate Change Workgroup, support EPA regions' efforts to supplement this strategy, and reach out to other Federal agencies with climate change interests.

PREPARATION OF NATIONAL LEGISLATION ON ADAPTATION

In 2009, the U.S. House of Representatives passed a bill that addressed both adaptation and mitigation actions. Titled the American Clean Energy and Security Act, it addresses both national and international aspects of adaptation. The bill includes the establishment of a National Climate Change Adaptation Programme, a Natural Resources Climate Change Adaptation Fund and a Natural Resources Climate Change Adaptation Policy. However, at the time of this writing, the U.S. Senate has not yet considered the bill, and substantial changes to the bill may be made before it is passed by both the Senate and the House of Representatives and signed by the President into law.

Source: USEPA; www.epa.gov/ow/climatechange/strategy.html

http://www.opencongress.org/bill/111-h2454/show

United States Department of State

WWF-World Wide Fund for Nature

As there is a need to understand the implications of climate change for water resources, their sustainable management and societal goals, it will be advantageous to establish dedicated teams involving various disciplines to carry out scientific activities on this topic. A regional climate outlook forum (RCOF) is a good example of such a team that brings together national, regional and international climate experts, on an operational basis, to produce regional climate outlooks based on input from National MeteoHydrological Services (NMHSs), regional institutions, regional climate centres (RCCs) and global producers of climate predictions (see also box 16).

Joint bodies, such as river basin commissions, should be responsible for the development of joint or coordinated adaptation strategies for transboundary basins and for following up their implementation and evaluating their effectiveness. The bodies need therefore to have the capacity and means to effectively undertake these tasks.

The lack of institutional capacity should not be a reason for not taking action. All countries need to take the initiative in building their own capacities to handle the challenges of climate change.

3.5 Education, capacity-building and communication

Education, capacity-building and communication are prerequisites for achieving sustainable development and essential tools for good governance and informed decision-making. They strengthen the capacity of individuals, groups, communities, organizations and countries to make judgements and choices in adapting to climate change.[9] Therefore, they should be an integral part of any adaptation strategy and should take place at all phases of the adaptation chain. Governments should play a proactive role in this regard, in partnership with stakeholders (as an example, see box 14).

Education and communication should aim at increasing awareness and improving understanding of the mechanisms that drive climate change as well as the potential environmental and socio-economic impacts. This should be targeted at all the stakeholders that participate in the governance process, including members of joint bodies, to ensure that everyone has the same basic understanding. Water management agencies and other related authorities should be willing to provide appropriate assistance to communities in support of increasing the understanding.

Education in the formal sector needs to take place at all points on the education timeline, from the early years through to higher learning. Throughout, the need for understanding and action from both a short- and long-term perspective is essential. Both the principles and the practical measures that can be taken regarding adaptation in response to climate change should be addressed. In this regard, education is important to prevent negative impacts of autonomous adaptation measures.

It is imperative that as much support as possible be provided to teachers and schools undertaking this effort. This means, among other things, as much as possible integrating the new learning into existing curricula and programmes, providing as many professional

development opportunities for teachers and school administrators as possible, and taking a "whole school" approach (creating the possibility of non-formal and informal learning) wherein all staff are committed to working sustainably.

Education in the formal sector must be supported by education in non-formal and informal settings, in clubs and other civil society forums. Actors responsible for formal education and those in non-formal and informal settings should be prepared to cooperate. This will not only support learning but, as well, enhance communication and capacity-building.

In addition, States should assist each other in capacity-building. In particular, States that are more advanced in terms of adaptation should assist the less advanced ones. The importance of the transfer of knowledge related to capacity-building through education and learning in formal, non-formal, informal settings cannot be over-estimated with respect to transboundary issues related to climate change.

Education programmes and communication strategies should be designed and implemented to meet the needs of target groups, taking into consideration such aspects as age, social roles and level of literacy. People at risk from climate change should be considered as a special target group. This can help to bring to people's attention the fact that they should take adaptation and mitigation into account in their own life decisions, e.g. whether to build in flood-prone areas and /or to use climate-proof construction methods.

[9] See also the UNECE Strategy for Education for Sustainable Development (CEP/AC.13/2005/3/Rev.1).

Box 14: Water Conservation in the Pembina Trails School Division: an example of an educational measure from Winnipeg, Manitoba, Canada

In Canada, responsibility for the formal education system lies with each of the ten provincial and three territorial governments. The school curriculum in each jurisdiction is somewhat different, but across school divisions within these jurisdictions there is a high degree of consistency. In the Province of Manitoba, the geography of the province is divided into school divisions that are responsible for operating schools in their respective divisions. Each school division is governed by a board of locally elected trustees.

For many years Pembina Trails School Division in Winnipeg has been incorporating sustainable practices in both facilities and operations and adult and student learning. Changes in equipment and new technologies have gone hand-in-hand with education of divisional staff, in particular maintenance and facility workers, teachers and students.

Through a five-year conservation, education and retrofitting project called Powersmart, the division has offset costs for utilities and water by over Canadian Dollar (CAD) 700,000 (approximately US$ 600,000). The Energy Manager also secured more than CAD 150,000 (approximately US$ 127,000) in grant funding from the provincial government and the province's major energy utility Manitoba Hydro for efficiency improvements. However, most of the savings were achieved through operational and behavioural improvements, not large investments in equipment.

Equipment changes included the installation of low flow automatic taps and fixtures throughout the Division, dual-flush toilets, and waterless urinals. Through the Green Manitoba (provincial government special operating agency) grant called Green School Initiative, school sustainable development teams are using funds to install more such toilets and urinals in their own schools. Students are also being encouraged to think about how much water they use and to try and reduce it.

The heightened awareness of water conservation throughout the Division can clearly be seen in student classroom activities. As part of the Powersmart programme, students look at their own family's domestic water usage and examine water usage by age of family member. Graphing and charting of results links well with the mathematics curriculum.

Forward-thinking educators have provided opportunities for students to work beyond the classroom and normal curriculum by using the lakes and water resources in the city and the surrounding areas. In winter, middle school students walk from their school to Fort Whyte Alive, an urban education centre of woods and lakes. Here they work with Arctic scientists who have examined the effects of climate change on ice conditions. Winnipeg is ideally suited for this kind of student study with feet of ice covering the rivers and lakes in the winter months.

One hour north of Winnipeg in Gimli, students board a Lake Winnipeg research vessel to observe and work with the research team studying the quality of lake water. In the summer, large algal blooms and swimming beaches closed for brief periods because of poor water quality give this learning opportunity immediacy and relevance.

Fort Richmond Collegiate, a high school in the Division, established a Wetland Centre of Excellence a few miles outside the city at Kelburn Farms. Here with pails of water and sponges students learn about the water cycle, how marshes receive water and other topics.

Throughout all of these activities students are taught the importance of protecting and conserving water, wetlands, rivers and lakes - which also improves their preparedness for possible future climate change impacts. Those impacts, and the need to take adaptation as well as mitigation measures, will make the continued study of the quantity and quality of Manitoba's water an essential area of student study.

Source: Pembina Trails School Division
http://www.pembinatrails.ca/

Chapter 4

Information and Monitoring Needs for Adaptation Strategies Design and Implementation

Adaptation to climate change requires a multistakeholder approach to identify data needs according to the principles of IWRM.

Data collection should cover all aspects of the hydrological cycle, considering the needs of the final users, but not be limited to it.

Data collection should also cover explicit information on water uses.

Information sharing between sectors, especially at the transboundary level, is essential to jointly assess the vulnerability to climate change impacts.

Historical monitoring stations should be maintained to have sufficient time series of data.

Monitoring and observation systems should be ready to adapt to the changes in information needs that could occur in the future, and should consider the interactions between the different variables.

Information for disaster risk reduction, e.g. considering environmental and social vulnerability assessment, is of crucial importance.

This chapter aims to identify the additional requirements that climate change adds to information and monitoring needs for water policies, strategies, implementation and operation. This information is required to support: (a) the assessment of current and projected climate changes; (b) the development of adaptation strategies, and (c) the calibration of models so they are able to assess vulnerability hot spots. Reference is made here to the UNECE Strategies on Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters,[10] which elaborate general approaches to information and monitoring needs, as well as to the World Meteorological Organization (WMO) Guide to Hydrological Practices.[11]

[10] Available at: http://www.unece.org/env/water/publications/pub74.htm.

[11] See the Guide to Hydrological Practices (WMO 168) for methodologies of information collection, density of hydrological observing networks and data accuracy and validation.

4.1 Definition of information needs

Information about climate change impacts is needed to help decision-making on the urgency and desirability of adaptive measures. As policymakers and managers working in health and water sectors should be able to understand and interpret the information, information needs should be identified by the policymakers and managers together with relevant experts. However, particularly in many developing countries, the different types of data needed are often not available. Such situations require step-by-step approaches towards information gathering.

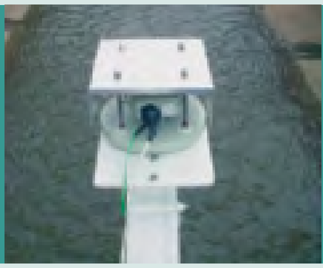
Quite often water-resources information has been collected for single specific purposes, such as the use and design of hydroelectricity schemes, water supply systems, water treatment systems, etc. The need for integrated water resources management that supports the understanding of interactions among the different components of the hydrological cycle and the different projects and users places a greater burden on the suppliers of information. Information needs to be sufficient and relevant for, and intelligible to, the various stakeholders in the different water-related sectors (e.g. navigation, hydropower, tourism, public health, agriculture, drinking water facilities). So a range of information is needed simultaneously, and has to be presented in different forms for different users.

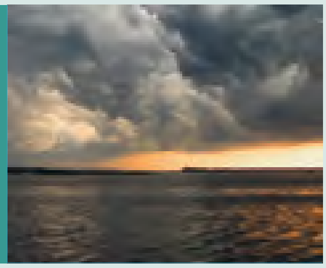
The national hydrological services and other providers of hydrological information (services for surface and ground-water, water quantity, water quality and hydropower) should therefore understand the needs of all their users, and not just those with whom they have traditionally dealt. For this reason, all relevant stakeholders should be involved in the process of defining information needs.

As a first priority, it is necessary to maintain existing and historical monitoring stations to have sufficient time series of data. Additionally, it is recommended to look ahead to data which may be required to assess expected emerging challenges and responses, for instance in land use changes, and to start collecting this information before the need for it actually occurs.

The process of specifying information needs should be based on an analysis of the water management issues related to climate change. Data and information needs should be defined for identifying:

- Potential effects of climate change on water resources under natural regimes;
- Requirements on the quality and quantity of water resources needed by specific uses (e.g. drinking water, irrigation, recreation) and functions of water resources (e.g. maintenance of aquatic life);
- Possible impacts on these uses and functions caused by climate change;
- Measures taken to address the impacts or improve the use or functioning of water resources, including environmental aspects (ecological status).





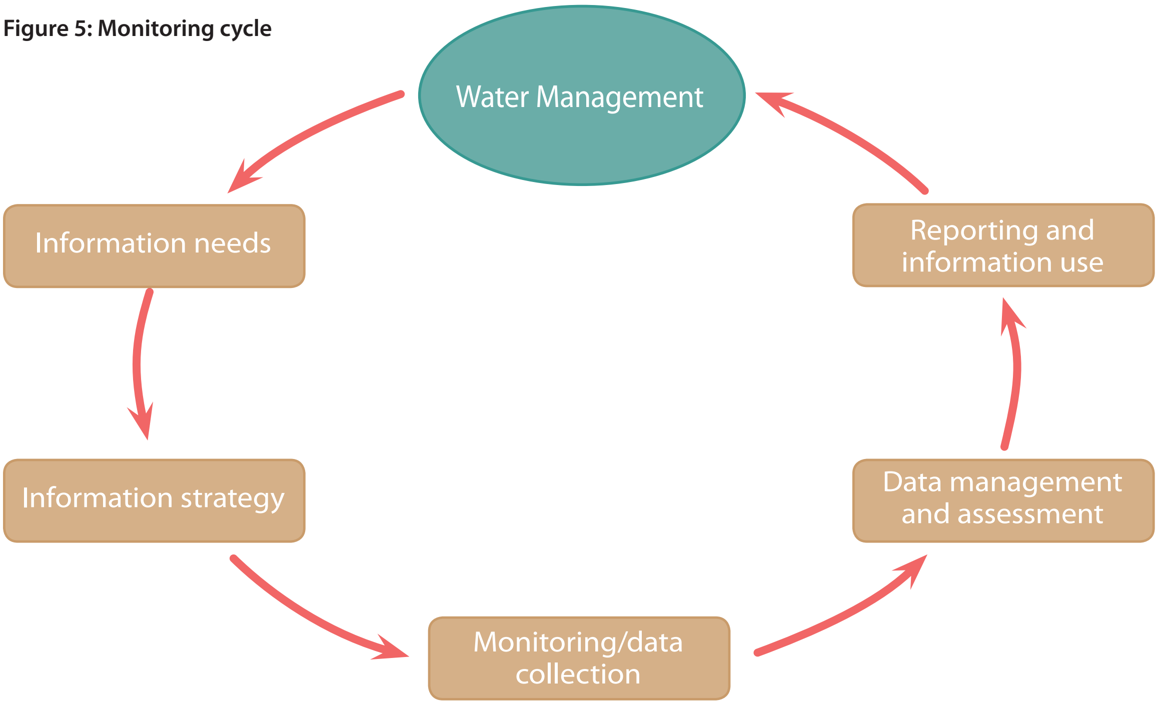
Adaptation strategies are based not only on information related to water management but also on socio-economic information and health hazards. Socio-economic information should help describe social vulnerability (e.g. risk maps "weighted" by population density, climate-dependent socio-economic sectors, health infrastructure and services, coping capacities). Health hazards may include factors that affect water quality (e.g. concentration of chemicals in water) and food safety, extreme weather events and changing meteorological conditions.[12]

The process of monitoring and assessment should principally be seen as a sequence of related activities that starts with the definition of information needs, and ends with the use of the information product (see figure 5 below). Successive activities in this monitoring cycle should be specified and designed on the basis of the required information product as well as the preceding part of the chain. In drawing up programmes for the monitoring and assessment of river basins, riparian countries should jointly consider all stages of the monitoring process. The evaluation of the information obtained may lead to new or redefined information needs, thus starting a new sequence of activities. In this way, the monitoring process will be improved.[13]

Information needs should be clearly determined for different target groups (policymakers, sectors, operators), dividing the information into relevant levels of time (strategic, tactical and operational), space (transboundary basin, national, and local levels), and purpose (early warning (operational level), recovery and long-term planning (strategic level)).

Climate models and hydrological models must ensure that the information produced is relevant for water management. Close cooperation between climate and water professionals is therefore imperative.

Figure 5: Monitoring cycle



Source: UNECE 2006.

[12] For further information, see ISDR Publications:
EWC III – Third International Conference on Early Warning: *Developing early warning systems – A checklist*
Hyogo Framework for Action 2005 - 2015: *Building the Resilience of Nations and Communities to Disasters.* Words Into Action: *A Guide for Implementing the Hyogo Framework.*
See also the Guidance on Water Supply and Sanitation in Extreme Weather Events, developed under the Protocol on Water and Health.
[13] For further information, see UNECE 2000: Guidelines on Monitoring and Assessment of Transboundary Rivers, 2000: http://www.unece.org/env/water/publications/documents/guidelinestransrivers2000.pdf

Box 15: The Four Elements of Effective Early Warning Systems, and Deriving Information Needs

Early warning systems focus on allowing individuals and communities threatened by hazards to react effectively (in sufficient time and in an appropriate manner) in order to reduce the impacts and damages of the hazard. To be effective and comprehensive, early warning systems should be composed of four inter-related elements: risk knowledge, monitoring and warning service, dissemination and communication, and response capability (see figure below). All of the elements should be strongly interconnected, and sustained by effective governance and institutional arrangements, including good communication strategies.

RISK KNOWLEDGE

This element aims at increasing knowledge about the risks individuals and communities face. Risk is a function of three factors: the magnitude of the hazard, the degree of exposure to the hazard and overall socio-economic and environmental vulnerability. Risk assessments should be carried out in advance to identify early warning system needs and prepare for response and disaster prevention activities. Risk assessments are done by collecting and analyzing data while taking into account the variability of hazards and the socio-economic vulnerabilities due to urbanization, rural land use change, environmental degradation and climate change.

MONITORING AND WARNING SERVICE

This element aims at providing the necessary information. Warning services must have a sound scientific basis for predicting and forecasting and must be reliable enough to operate continuously. This will ensure accurate warnings in time to allow action. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks.

RISK KNOWLEDGE

Systematically collect data and undertake risk assessments

Are the hazards and the vulnerabilities well known?

What are the patterns and trends in these factors?

Are risk maps and data widely available?

MONITORING & WARNING SERVICE

Develop hazard monitoring and early warning service

Are the right parameters being monitored?

Is there a sound scientific basis for making forecasts?

Can accurate and timely warnings be generated?

DISSEMINATION & COMMUNICATION

Communicate risk information and early warnings

Do warnings reach all of those at risk?

Are the risks and warnings understood?

Is the warning information clear and usable?

RESPONSE CAPABILITY

Build national and community response capabilities

Are response plans up to date and tested?

Are local capabilities and knowledge made use of?

Are people prepared and ready to act on warnings?

DISSEMINATION AND COMMUNICATION

This element aims at informing individuals and communities about risks and actions. To be effective, warnings must reach the individuals and communities at risk. This means also that warnings should contain clear, useful information leading to proper responses. Communication channels and tools must be identified beforehand and established at regional, national and community levels. To ensure full dissemination of warnings, the use of multiple and coherent communication channels is necessary.

RESPONSE CAPABILITY

This element aims at improving the capability to respond to hazards. Communities' education and preparedness programmes should be established to ensure that the proper response and action is undertaken by the individuals and communities at risk at the right time. Disaster management plans should be operational, well practiced and tested.

Source: International Strategy for Disaster Reduction (ISDR) 2006. EWC III – Third International Conference on Early Warning: Developing early warning systems – A checklist. Available online at: http://www.unisdr.org/ppew/info-resources/ewc3/checklist/English.pdf

Regional Climate Outlook Fora Worldwide

Box 16: Regional Climate Outlook Forums

A regional climate outlook forum (RCOF) brings together climate experts, sectoral users and policymakers, to produce regional climate outlooks based on input from National MeteoHydrological Services (NMHSs), regional institutions, Regional climate centres (RCCs) and global producers of climate predictions. RCOFs assess the likely implications of the future climate on the most pertinent socio-economic sectors in the given region.

RCOFs were originally designed to focus on seasonal prediction, and have significantly contributed to adaptation to climate variability. The concept has the potential to be extended to develop capacities to adapt to climate change. Regional assessments of observed and projected climate change, including the development of downscaled climate change scenario products for impact assessment, can be included in the product portfolio of RCOFs.

The RCOF process, pioneered in Africa but still in the beginning phase in Europe, typically includes the following components:

- Meetings of regional and international climate experts to develop a consensus for the regional climate outlook, typically in a probabilistic form;
- The Forum itself, which involves both climate scientists and representatives from the user sectors (agriculture and food security, water resources, energy production and distribution, public health, other sectors such as tourism, transportation, urban planning, etc.) for identification of impacts and implications, and the formulation of response strategies;
- A training workshop on seasonal climate prediction to strengthen the capacity of national and regional climate scientists;
- Special outreach sessions involving media experts, to develop effective communications strategies.

RCOFs also review obstacles to the use of climate information, experiences and successful lessons regarding applications of the past RCOF products, and enhance sector-specific applications. The development of RCOFs requires good seasonal forecasting skills. These RCOFs then lead to national forums to develop detailed national-scale climate outlooks and risk information including warnings which can be communicated to decision makers and the public.

References: Ogallo, L., P. et al., 2008. *Adapting to climate variability and change: the Climate Outlook Forum process.* In WMO Bulletin 57 (2): 93–103.

Ogallo, L. and C. Oludhe, 2009. Climate information in decision-making in the Greater Horn of Africa: lessons and experiences. In *WMO Bulletin* 58 (3): 184–188. Available online at: http://www.wmo.int/pages/publications/bulletin_en/documents/58_3_ogallo_en.pdf.

4.2 Types of information

There is a need for information related to the downscaling of climate models (general circulation models) to the transboundary basin (catchment) and local levels (see chapter 5). In many cases the results from downscaling may not provide reliable projections of future conditions. So clear communication on the absence or limitations of projections produced through downscaling is as important to communicate clearly as the downscaling results themselves.

Information needs related to climate change adaptation not only relate to climate prediction but include, inter alia, geographic and socio-economic information (from e.g. national census data, development plans, etc.). These data must be available in order to enable development of adaptation measures at a scale ranging from local to national and transboundary levels. Where such data are not available and will take a long time to generate (as is the case in much of the less-industrialized world) robust approaches for understanding and guiding adaptation in data-limited environments are essential.

Monitoring systems should be designed to capture early signals of climate change impacts and differentiate them from signals of impacts from other pressures, and also to monitor the direction of long-term gradual impacts and trends.

Box 17: Examples of Simplified Meteorological, Hydrological, Morphological Data and Data on Water Quality Needed for Scenarios and Vulnerability assessment

METEOROLOGICAL DATA:

- Precipitation (total and intensity), e.g., rainfall, snow, and fog-drip;
- Temperature (atmospheric and soil);
- Evapotranspiration;

HYDROLOGICAL DATA:

- Water levels in river and discharge, lake levels and reservoir storage, including operational rules;
- Ice phenomena;
- Sea levels;
- Groundwater levels;
- Nationally generated water resources compared with transboundary water resources;

MORPHOLOGICAL DATA:

- Sediment concentrations and loads in rivers;
- Area of glaciations;
- Coastal erosion;
- Topography;
- Land use;

WATER QUALITY DATA:

- Water quality (bacteriological, chemical, and physical) of surface water and groundwater;
- Coastal saline intrusion, especially in aquifers used for the production of drinking water;
- Bio-indicators;
- Water temperature;

STATISTICS RELATED TO THESE ELEMENTS INCLUDE:

- Homogeneity of data;
- Mean annual, monthly, seasonal or daily values;
- Maximal, minimal, and selected percentiles and respective return periods;
- Measures of variability, such as the standard deviation;
- Continuous records in the form, for example, of a river-flow hydrograph.

The design of a monitoring programme includes the selection of parameters, locations, sampling frequencies, field measurements and laboratory analyses. The parameters, type of samples, sampling frequency and station location must be chosen carefully with respect to information needs. The field equipment and laboratory facilities must be selected to match the information needs. The calibration of models requires long time-series of hydrometeorological data. Due care should be taken to ensure that data are quality controlled and homogenized. Main locations of gauging stations are usually on the lower reaches of rivers, immediately upstream of the river mouth or where the rivers cross borders, near the confluence with tributaries and at major cities along the river. All these areas are often influenced by human activities, and so have altered hydraulic conditions. To better identify changes in trends caused by climate change and not by anthropogenic influence, hydrological and meteorological observing stations could be established in pristine river basins (those with minimal anthropogenic change). These are unlikely to be available in many of the more densely settled parts of the world. Data homogenization can filter out non-climatic effects from available time series.

Data needed for impacts modelling and subsequent vulnerability assessment at the national, international and river basin levels include hydrological, meteorological, morphological and water quality characteristics (see also box 17). Statistical analysis of the previous data series, as well as statistics on diseases caused by water factors (taking into consideration age, sex, local geographical conditions, etc.) is also essential.

Historical data should be used to identify trends, both gradual (to recognize changes in climatic conditions) as well as extremes (to identify the potential magnitude of climatic changes). For instance, data on lake levels are useful for analysis of gradual climate impacts on surface waters, as they often reflect the effects of a changing ratio between evapotranspiration and precipitation. Similarly, predictions and projections should include long-term trends (for the development of adaptation strategies), seasonal variations and the magnitude of extreme events (to identify and develop short-term measures).

Responses of groundwater systems to climate change are particularly difficult to predict. For example, while predictions may suggest an increase in precipitation for a given region, if this precipitation occurs at a higher rate and over a shorter period of time, there may be less recharge to the groundwater system than if the precipitation is more evenly distributed. Special attention should therefore be devoted to monitoring groundwater systems.

In addition to the more conventional measurements listed above, information on other aspects of the freshwater environment and of the wider environment of which freshwater is a component are needed. These include:

- Water demand for industrial, domestic and agricultural use; of these three, agricultural use tends to dominate. These are significant modifiers of the hydrological cycle; future changes in water demand should be clearly indicated by the respective users (based on their economic planning);

- Attributes of rivers and required volumes of water related to in-stream uses, (e.g. freshwater fishery habitats or recreation, navigation, etc.) as well as aquifers and lakes;

- Transboundary basin characteristics (e.g. vegetation patterns, soil moisture, topography, aquifer characteristics, and land use planning) that may affect the hydrological cycle;

- Environmental problems, e.g. eutrophication of lakes and damage to natural freshwater and estuarine ecosystems. Environmental protection agencies should also express their data needs.

Water supply systems may need additional monitoring for microbiological or chemical contamination following floods or drought periods (pipe infiltration, increased chlorination, increased concentration of contaminants) and continuous monitoring of the loss of water from pipes is necessary, and not only during extreme events.

Monitoring in long-term and short-term critical conditions should be linked with systems of surveillance of water-related disease to ensure prevention of health risks. For surveillance purposes, ad hoc development of indicators will provide information and allow assessment of progress.

Socio economic information, such as on land use planning, is needed for feeding into the vulnerability assessment.

Information is also needed which can help to evaluate the effectiveness of adaptation measures (see chapter 9).

4.3 Sources of information

In order to use climate information in water resources management, a reliable monitoring system is of the utmost importance. Data reliability directly affects the accuracy of numerical models, both climate predictions and hydrological models. Historical data are needed to develop and calibrate models. An integrated nationwide (or transboundary basin-wide) observation system is therefore necessary. In this context also the importance of groundwater monitoring should be strengthened.

National data collection and management systems are often inconsistent and incomplete at the international and even at the national level. Especially for the monitoring of health effects of extended drought events and/or floods, appropriate indicators still need to be developed and adopted at the national level. The experience gained in the international Emergency Events Database (EM-DAT) of the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) provides a good example that can be applied in many countries.

Hydrological Cycle Observing Networks should be developed and implemented at the transboundary scale, rather than at administrative (e.g. regional, provincial) scale. Promoting data sharing as in the WHYCOS (World Hydrological Cycle Observing System) projects implemented by WMO is particularly important for water management at transboundary basin level. Remote sensing capabilities can be particularly useful in providing data at the national and regional level. In this context, the integration of Earth observations, prediction, and decision-support systems under the Global Climate Observing System (GCOS) or the Global Earth Observation System of Systems (GEOSS) is particularly useful.

Hydrological or hydrometeorological services or related agencies have been established in countries for systematic water resources data collection, archiving, and dissemination at the national level. Their primary role is to provide information to decision makers on the status and trends of water resources.

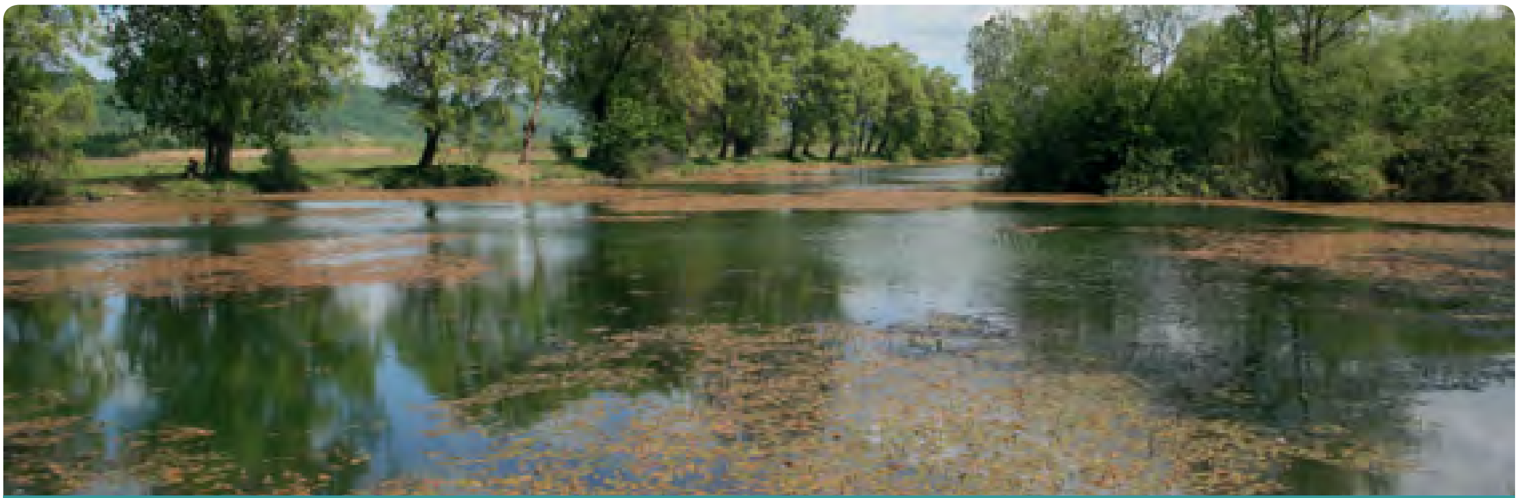
The existing international sources of information are data sources maintained for example by relevant United Nations agencies, such as the United Nations Global Environment Monitoring System (GEMS), the Information System on Water and Agriculture of the United Nations Food and Agricultural Organization (FAO AQUASTAT) or the World Metrological Organization's Hydrological Information Referral Service (WMO INFOHYDRO), the International Groundwater Assessment Centre (IGRAC) for groundwater, the Global Runoff Data Centre (GRDC) for surface water and World Data Centres, etc. When focusing on transboundary basins, information is often available from the river basin commissions where data sources are established.

The scope and flexibility of monitoring systems should be such that they can gather information which is important for the protection of human health in extreme weather events. Information should cover all possible water-related exposure routes (e.g. direct ingestion, ingestion through contaminated food, skin contact and droplet distribution) that may constitute a risk to human health. Monitoring systems should also be able to adapt to changing scenarios of diffuse and scattered point-sources in flooding events or drought episodes. The information derived from such information systems should be used to re-examine land- and water-use planning and to define and implement changes that will protect human health to the greatest extent possible. For example, if serious contamination is found on land zoned for agricultural purposes, it may be necessary to rezone the land for exclusively industrial use.

The design and updating of data collection networks, especially the main stations, should be coordinated to ensure that the different elements of the water cycle are sufficiently related, both in number and location, to achieve an integrated monitoring network. Such an approach enhances the information content of the data sets for both present and unforeseen future needs.

Information technology implementation should provide for the open source exchange of information among sectors for preventive (early warning), response, and long-term planning purposes. Integration between in situ and satellite information (e.g. the Global Monitoring for Environment and Security (GMES) and the Infrastructure for Spatial Information in the European Community (INSPIRE)) is also advisable.

For geographic and socio-economic information, other sources need to be used, such as National Geographical or Geological Institutes (both military and civilian), land use plans (usually established at the local level), relevant ministries, demographic and statistical national institutes or national census surveys.



Box 18: Joint Monitoring Under the Tisza Group of the International Commission for the Protection of the Danube River

The Tisza Group was established in 2004 under the EU Presidency of the International Commission for the Protection of the Danube River (ICPDR) when the five countries concerned signed the Tisza Memorandum of Understanding. The Tisza Group is aiming at providing a platform for strengthening coordination and information exchange related to international, regional and national activities in the Tisza River basin (TRB) to ensure the harmonization and effectiveness of related efforts.

The Tisza Group countries agreed their main objective was to prepare a plan (the Tisza River Basin Management Plan) by 2009, which integrates issues of water quality and quantity, land and water management, flood and drought. The first activity of the Group was the preparation of the Tisza Analysis Report by 2007, which describes the Tisza River and its basin, identifies the significant environmental and water management problems in relation to water quality and quantity, and creates the basis for further steps. The Tisza Analysis and the Integrated Tisza River Basin Management Plan build on the principles of EU water legislation, in particular the Water Framework Directive but go beyond this, aiming at the same time to implement the EU Flood Directive as well as the EU Communication on water scarcity and droughts.

INFORMATION AND DATA EXCHANGE IN THE FRAME OF THE ICPDR

In accordance with the working process of the ICPDR expert groups, the ICPDR Tisza Group meets regularly during the year. National delegates, technical experts, and members of civil society and of the scientific community cooperate in the Group, which represents all Tisza countries: Ukraine, Romania, Slovakia, Hungary and Serbia. The information that is collected for the Tisza sub-basin has a higher resolution than that collected for the Danube basin.

Based on the requirements of the EU WFD, the Danube River basin (DRB) GIS (DanubeGIS[14]) provides a platform for exchanging, harmonizing and viewing geo-information and related issues in both the Danube and the Tisza on a basin-wide scale.

MONITORING NETWORKS ON WATER STATUS

In 1995 the Transnational Monitoring Network (TNMN) – a basin-wide monitoring network of the ICPDR – was established with the main objective of providing an overview of the overall status and long-term changes of surface water and, where necessary, groundwater status in a basin-wide context, with particular attention paid to the transboundary pollution load. In 2005, five TNMN stations were operating in the Tisza River basin.

The ICPDR and ICPDR Tisza Group recognized the importance of climate change and extreme climate conditions for the water status. The information gathered may be used in the future to reflect or add supplementary information on the possible impacts of climate changes.

In 2009, for the purposes of the river basin management plans (Danube and Tisza River Basins), the results and outcomes of the ongoing climate change research projects will be summarized.

Source: ICPDR Secretariat, www.icpdr.org
http://www.icpdr.org/icpdr-pages/tisza_group.htm

4.4 Joint information systems and exchange of information

In a transboundary context, a comparison of climate change projections and projected impacts on water resources is extremely important. At present, those developed by riparian countries often show a difference. Common scenarios of climate change for transboundary basins should also be developed. Joint or harmonized impact assessments are very important to avoid potential conflict of policies due to diverging projections.

To support effective cooperation in climate adaptation at the transboundary basin level, the development of joint monitoring and joint information systems (such as databases or GIS systems) is recommended (box 18). Such systems should be based on an agreement on the information to be shared and on which country will be responsible for producing what information. Existing systems should be adapted to include climate change issues. Where they exist, joint bodies should be responsible for this.

If a joint information system is not feasible, regular and also operational data and information exchange between different countries, bodies and sectors is needed. This includes exchange of information on adaptation plans and measures to enable riparian countries to harmonize their adaptation activities, and the exchange of data permitting the improvement of climate and hydrological prediction models. A data comparability procedure has to be established between countries adopting different methods of data collection (different methods of data surveying, instruments, procedures, etc.).

[14] www.danubegis.org

Box 19: Summary of Emergent Pathogens

	PATHOGEN	HEALTH SIGNIFICANCE	INFECTION CAUSED
Viruses:	Norovirus GGI and GGII	High	Gastroenteritis
	Sapovirus	High	Gastroenteritis
	Hepatitis A virus	High	Hepatitis
	Rotavirus	High	Gastroenteritis
	Enterovirus	High	Gastroenteritis
	Adenovirus	High	Respiratory & intestinal
	Avian influenza virus#	Low	Influenza
Bacteria:	pathogenic *Escherichia coli*	High	Gastroenteritis
	Campylobacter jejuni, C. coli	High	Gastroenteritis
	Helicobacter pylori	High	Stomach & duodenal ulcer
	Legionella pneumophila	High	Pneumonia
	Vibrio cholerae	High	Cholera
	Vibrio parahaemolyticus#	Medium	Wound infections, otitis and
	Vibrio vulnificus#	Low	lethal septicaemia
	Vibrio alginolyticus	Low	Gastroenteritis, respiratory
	Toxic cyanobacteria	Medium	dysfunctions, allergic reactions
Protozoa:	Cryptosporidium spp.	High	Gastroenteritis
	Giardia spp	High	Gastroenteritis
	Naegleria fowleri#	Low	Meningoencephalitis
	Acanthamoeba spp.#	Low	Keratitis, blindness

Taxa labelled with # are considered potentially emerging.

Source: WHO 2003. Emerging Issues in Water and Infectious Disease. Available online at: http://www.who.int/water_sanitation_health/emerging/emergingissues/en/

Exchange of information between riparian countries is a main obligation of the Water Convention and is required by many international agreements. According to resolution 25 WMO member countries should also provide those hydrological data and products necessary for the provision of services in support of the protection of life and property and for the well-being of all peoples on a free and unrestricted basis.[15]

Data should also be made publicly available, except in cases where disclosure to the public might damage confidentiality provided for under national law; international relations, national defence or public security; the course of justice; the confidentiality of commercial and industrial information (where such confidentiality is protected by law to protect a legitimate economic interest); intellectual property rights; etc. In such cases, data should be processed so that it cannot be used for purposes other than climate change adaptation.

4.5 Design of adaptive monitoring systems

Because of the inherent uncertainties of projections, adaptation to climate change is a process that requires continuous modification to account for improved insights. In addition, cooperation between water management and many different sectors is needed, as well as the involvement of the public at large. Monitoring systems consequently must be developed in such a way that they support those characteristics.

The information as collected should be made available for other interested audiences besides policymakers and water managers (e.g. other sectors, the public). A substantial problem in disseminating information to a wide audience is that translating the information produced by one group of professionals into a form that other professionals can use is often difficult. To overcome this problem, dialogue is necessary between the groups about the available information. The involvement of the media and education sectors is also needed.

Monitoring programmes taking account of the inherent uncertainties should be adaptive, focusing not only on the state of different variables, but also on the links and feedbacks between them. In addition, the information-producing system must support the complete process, from problem identification to evaluation of measures, including all the in-between steps. Regular reviewing of monitoring network data and information exchange in the transboundary context, including common assessment, is of great importance.

Adaptation of monitoring systems should take into consideration emerging health hazards due to climate change through monitoring additional relevant pathogens (see box 19).

[15] See WMO 1999. Exchange of hydrological data and products a.k.a. Resolution 25 adopted by WMO Congress General XIII.

Chapter 5

Scenarios and Models for Impact Assessment and Water Resources Management

Scenarios and models are tools that help to incorporate uncertainty about what will happen in the future into planning. As a simplification, one could say that scenarios are used to create alternative images of how the future might unfold, while models are used to provide information on these possible futures.

Models are needed to work on a spatial scale fine enough to allow assessment of the possible future impacts in a river basin. Such models need observation data on that scale to be able to calibrate and to run the models and to evaluate the results.

Riparian countries should develop common scenarios and models to develop a joint understanding of the effects of climate change. Common scenario development also permits a more rational use of the limited financial resources available.

5.1 Introduction

This chapter aims to describe how scenarios and models support water management in the light of climate change, by describing the steps involved in the process of developing scenarios and using models for projections. These projections are built on available information and feed into the vulnerability assessments. Figure 6 provides an overview of how data, scenarios and models are used to develop an adaptation strategy for climate change.

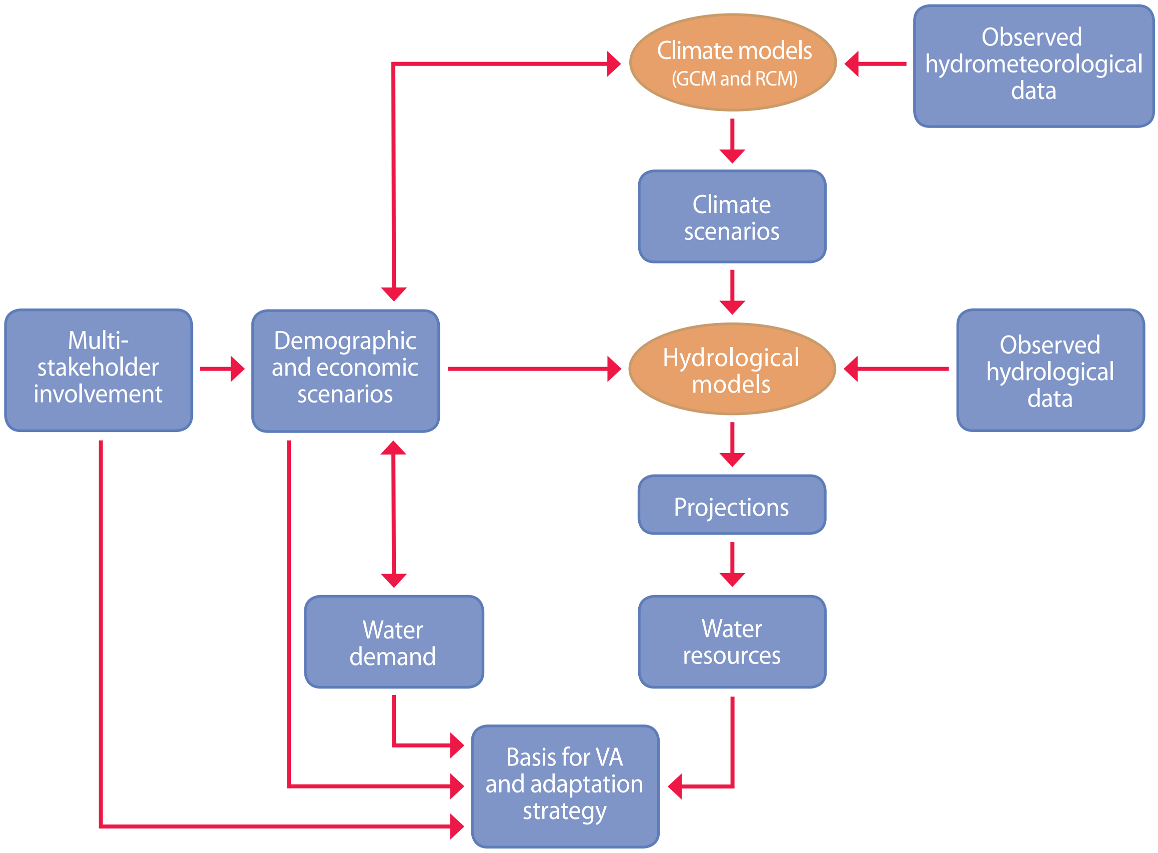
There is a debate in the climate science and impacts community about how best to support adaptation decision-making with climate change information. One school of thought focuses on the need for accurate, high-resolution (regional-scale) climate forecasts; once those capabilities have been developed, planning for adaptation can proceed. According to this school, scenarios and models are tools to handle the uncertainty of a changing situation by providing information on possible futures; these in turn depend on policy choices. Another school of thought argues that due to current limitations in modelling capabilities, assessing and responding to climate change should be approached from the perspective of risk assessment and management rather than as a prediction problem. The second school recognizes that climate models have furthered our understanding of climate change based on scenarios of GHG emissions and other forcings, and that the ability of those models to reproduce observations has improved.

However, substantial limitations remain, especially in projecting impacts at a scale relevant for hydrological forecasting. Furthermore, climate is only one of many important processes that will influence water, and often it is not the most important factor (compared, for example, to deterioration of water quality or to increasing water demand due to demographic pressure). Therefore this school of thought recommends other methods to reduce uncertainty such as increasing resilience (see section 7.3).

This Guidance does not choose either approach but pursues a twin-track approach in which all measures are taken based on the best available information, while at the same time increasing the knowledge base in order to improve forecasts and thus develop better capabilities for adaptation planning. Adaptation planners should be aware of the limitations of scenarios and choose the best method to deal with uncertainty based on the local context, for example depending on data availability. This chapter largely deals with developing better understanding of future situations through modelling and forecasting while Chapter 6 deals with vulnerability and risk management approaches.

By avoiding an analysis approach that places climate prediction at its heart, successful adaptation strategies can be developed in the face of deep uncertainty with the use of scenarios and models. Decision-makers should systematically examine the performance of their adaptation strategies over a wide range of plausible futures, which are driven by uncertainty about the future state of climate and many other economic, political, and cultural factors and the resulting vulnerability. They should choose a strategy they find sufficiently robust across these alternative futures.

Figure 6: Overview of the process towards the adaptation strategy





Such an approach can identify successful adaptation strategies without accurate and precise predictions of future climate.

Demographic changes and economic and socio-economic developments influence greenhouse gas emissions and the hydrological cycle, and have impacts on water demand. Based on the current and future social, economic and environmental goals set out by countries, demographic and economic scenarios have to be developed that will probably differ by region. Based on these different socio-economic (and emission) scenarios, General Circulation Models (GCMs) and Regional Climate Models (RCMs) can provide information on possible future climate conditions (climate scenarios). GCMs estimate the effect that greenhouse gas and aerosol emissions have on the global climate and describe important physical elements and processes in the atmosphere, oceans and on the land surface that make up the climate system. RCMs provide similar information, with better (finer) resolution. RCMs are therefore more suitable for developing water resource projections and adaptation strategies at the river basin level. The developed socio-economic scenarios, together with the projected data from the climate models, are the basic input for hydrological models. These models calculate the hydrological responses to changes in key climatic variables based on local features such as soil characteristics, the type and density of vegetation cover, and land use characteristics. The models provide output on the future hydrological conditions in a river basin. The model output includes information on available water resources as well as water demands, thus providing background information for assessing the vulnerability of water resources in a basin and for deciding on adaptation measures.

IPCC has developed four different narrative storylines (socio-economic scenarios) to describe the relationships between emission-driving forces and their evolution. Those scenarios are used to drive climate models to develop climate scenarios. In this way, the Special Report on Emissions Scenarios (SRES) developed by IPCC assists in climate change analysis, including climate modelling and the assessment of impacts, adaptation and mitigation.

Limitations to adaptation exist in the sense that forecasts will never be exact. Adapting to climate change will in many cases be equivalent to preparing for a range of potential scenarios. Decisions should focus on those scenarios that are more likely and that are likely to have substantial water management impacts. It is crucial to adapt or develop plans with sufficient flexibility to reflect the increased level of evidence. In developing those plans it is vital to understand that identifying a most likely scenario is difficult if not impossible – a range of plausible scenarios must be considered. In addition, where uncertainties are particularly high regarding the directions or nature of change in hydrological systems, interventions selected should be sufficiently flexible to deliver benefits under a range of conditions rather than being designed for what are thought to be the "most likely" future conditions. For example, in the case of flooding, designs that allow for "safe failure" are preferable to those that may function up to a specific flood level, but after that would fail catastrophically.

Many drivers need to be taken into account when choosing or developing scenarios. Some include demographic developments and land use changes such as population growth that can result in increased demands on water quality and quantity, or urbanization and intensification of land use, which shortens the run-off travel time and may cause flooding. Economic development is another driver likely to put greater pressure on natural resources, particularly water and energy. Conversely, changes in climatic conditions can have effects on demographic and economic developments. These feedbacks should be taken into consideration when choosing the most probable scenario.

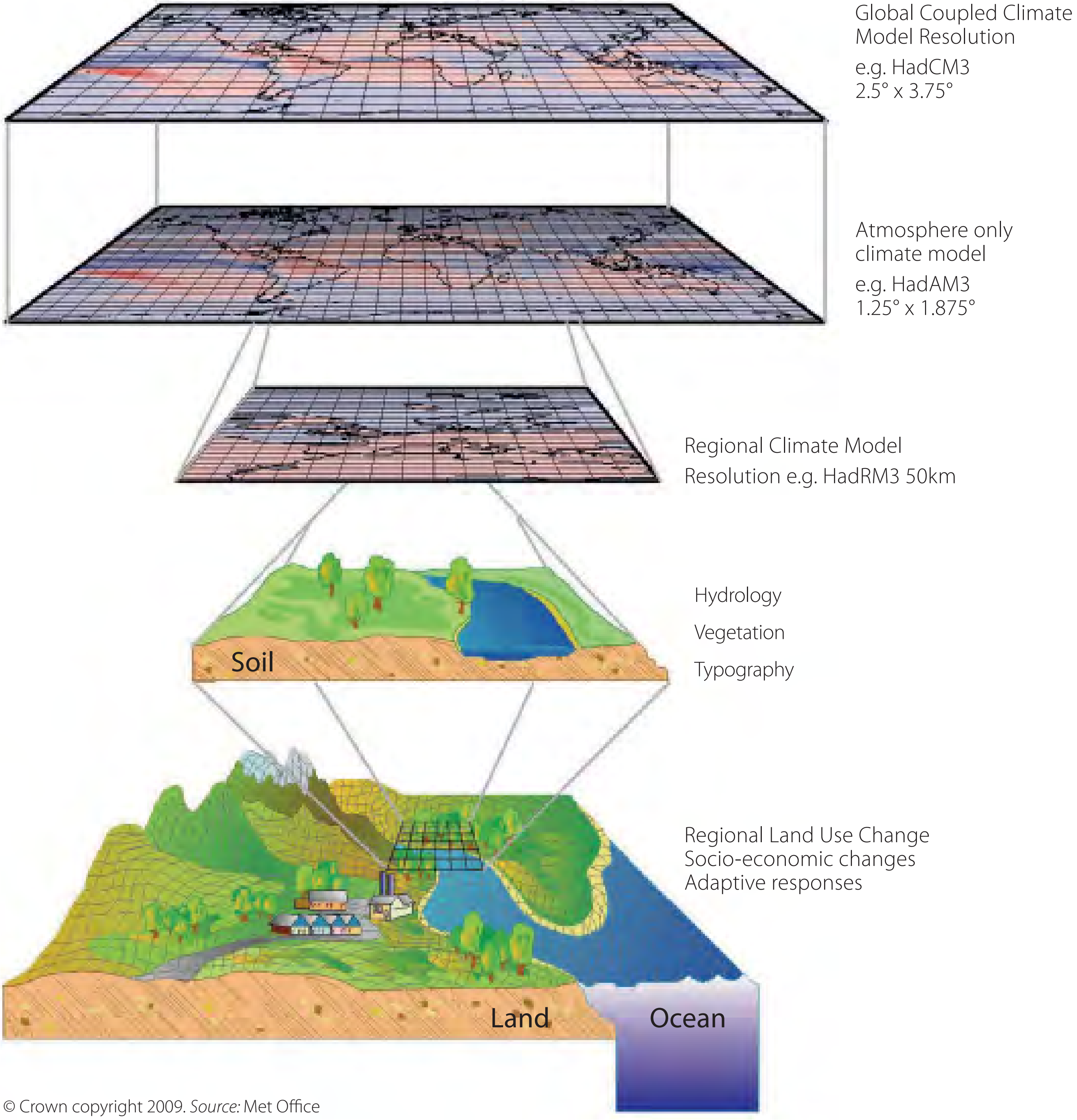
Scenarios should be chosen according to the local conditions and in consultation with relevant stakeholders, considering different conflicting interests.

Uncertainties in projected changes in the hydrological system include uncertainty in the variability of the climate system, uncertainty in future greenhouse gas and aerosol emissions, the translation of these emissions into climate change projections, and hydrological model uncertainty. Scenarios are used to allow decision makers to manage this uncertainty by identifying the highest vulnerability as well as identifying the adaptation strategies that are more robust with respect to this uncertainty.

5.2 Downscaling of models

General Circulation Models (GCMs) are mathematical models used to simulate the present and the projected future climate. GCMs typically have a 100 –200 km grid size resolution. The latest developments in modelling have made it possible to run GCMs with less than 100 km grid size resolution. However, this resolution does not permit an appropriate estimation of hydrological responses to climate change and consequently does not provide sufficient information to develop adaptation strategies on a river basin scale. To be able to develop model outputs at the basin scale, which is needed to develop adaptation options, there is a need to develop models at a finer scale (downscaling).

Figure 7: Dynamic downscaling



Two approaches for downscaling GCMs to local and/or regional scales suitable for hydrological impact studies have been developed. The first is based on dynamically simulating physical processes at sub grid level (figure 7). The second is based on statistically transforming coarse-scale climate projections to a smaller scale using observed relationships between climates at the two spatial resolutions, where the observed relationships are derived from a comparison of data from the GCM with observed meteorological data. The choice of the most appropriate downscaling technique partly depends on the variables, seasons and regions of interest. Applying both in parallel is advisable for calibration of both models.

Climate models are important tools for understanding and simulating climate. Calibrating those models is needed to ensure that the models reliably capture the physical and chemical processes the model describes. This calibration is achieved by comparing the model outputs with observed data. A model's capability to accurately calculate historical variables gives confidence that the model's projections will be accurate in predicting slow evolutions in mean climate (but not necessarily how weather extremes and climate variability will change). To be able to calibrate models at finer spatial scales, observational data on that scale are needed.

Box 20: The European Flood Alert System

Early warning on floods is essential to initiate in good time measures such as releasing water from lakes/reservoirs to increase flood storage, opening temporary flood polders, building up temporary flood walls, preparing evacuation of people and livestock, and organising pumping installations and sandbags, either in a national context or with international assistance (e.g. the European Commission's Monitoring and Information Centre (MIC)).

This is exactly why – following the disastrous floods in the Elbe and Danube river basins in August 2002 – the European Commission (EC) started the development and testing of a European Flood Alert System (EFAS), aimed at early flood warning to complement existing national systems. Being developed and tested at the EC Joint Research Centre (JRC), EFAS is capable of providing medium-range flood simulations across Europe with a lead-time (time between the detection and the arrival of the flood) of between 3 and 10 days. Successful early warnings are being achieved, especially in the range of 3 to 6 days before a flood, with for example the August 2005 flood in the northern Alps, as well as the Elbe/Danube snow melt flooding in March/April 2006. There have also been several flood warnings for Romanian rivers, including in August 2008, and the Po flooding in April 2009. In several of these cases civil protection activities were able to start earlier thanks to EFAS.

Twice a day EFAS uses approximately 70 different numerical weather forecasts from the European Centre for Medium Range Weather Forecasts (ECMWF), Deutscher WetterDienst (DWD) and the European Consortium on Meteorology – Limited Area Ensemble Prediction System (COSMO-LEPS), as well as near-real time weather and river-discharge observations from several European providers. This is entered into a hydrological modelling system called LISFLOOD, which then produces 70 flood forecasts. Statistical comparison with historical floods enables EFAS to determine whether critical flood alert thresholds may be exceeded in the forecast time window. An email is sent to the member National Hydrological Services (NHS) warning that a flood is likely to happen. The NHS can follow the detailed results and overview of all alerts on a protected webserver.

The benefit of EFAS is two-fold. First, it aims to provide the EC with useful information for the preparation and management of aid before and during a flood crisis, though its Community Mechanism on Civil Protection coordinated via the MIC in Brussels. Second, the present network of 25 National and/or Regional Hydrological Services benefits from additional medium-range flood information that can contribute to increased preparedness in a forthcoming flood.

Membership of EFAS is free and is open to national and regional hydrological services which have a role in operational national/regional flood warning, upon signing a simple memorandum of understanding clarifying roles and liabilities, without obligations for NHS. At present, EFAS covers Europe as far as 30 degrees east (including Finland, the Baltic States and the Republic of Moldova). It could extend further if there is a strong demand from the countries involved.

As an essential part of EFAS, an exchange of near-real time river flow data has been established with the Hydrological Services, in close collaboration with the Global Run-off Data Centre (GRDC) in Koblenz, Germany, an initiative of WMO. These data permit not only better forecasting, but also essential verification of forecasts for further improvements to the system.

Future challenges for EFAS are to accommodate the increased use of satellite information (rainfall, snow cover and amount/water equivalent) through data assimilation techniques, as well as the use of global weather ensembles which have been shown to allow even longer flood warning lead times.

Preparations for an operational phase of EFAS have started. It is planned to become operational from 2011.

Webpages:
http://floods.jrc.ec.europa.eu, http://efas.jrc.ec.europa.eu/

5.3 Criteria for the selection and application of hydrological models

Models are roughly divided into statistical (black box) models and physical-based (deterministic or conceptual) models. The latter are generally considered to be more reliable, particularly in assessing the impacts of climate change. A range of conceptual models has been developed for operational hydrological forecasting.

Unless the national institutions in charge of hydrological data processing and forecasting develop a suitable model themselves, they are faced with the difficulty of choosing between the many models proposed for operational use. The selection of a particular model will depend on specific conditions and the objective of modelling. When selecting a model, the purposes of the model, the climatic and physiographical characteristics of the basin, the quality of the data available, both in time and space, the possible need for reducing model parameters from smaller catchments to larger catchments, and the ability of the model to be upgraded on the basis of current hydrometeorological conditions and climate scenarios need to be taken into account. The selection should also focus on the particular models that have proven effective in the past.

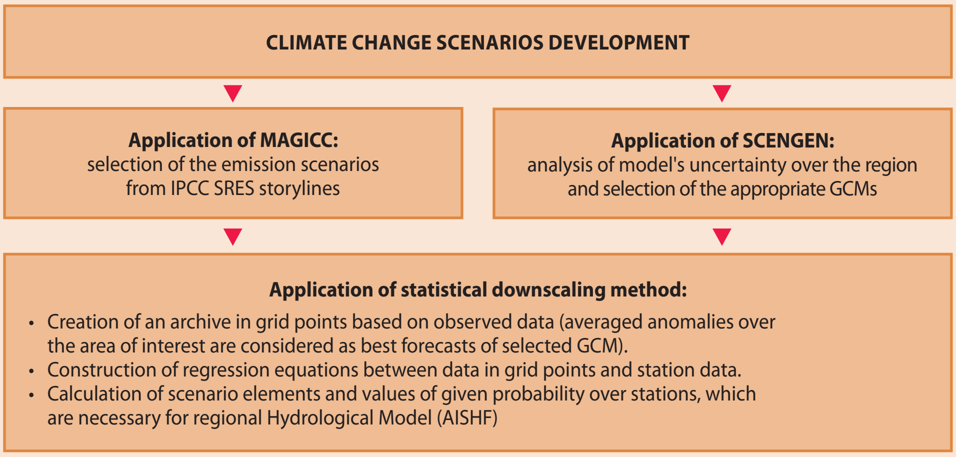
Historical data collected during routine operations are useful for calibrating the model and improving its performance. Calibration and

Box 21: Scenarios and Models for Assessment of Climate Change Impacts on Water Resources in Uzbekistan (Aral Sea basin)

Regional climate change projection

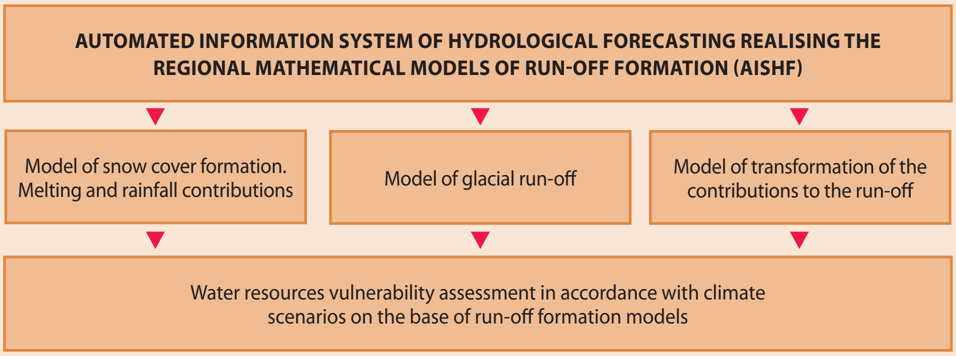
For the assessment of climate change impact, climate scenarios have been developed on the basis of models of the global circulation of the atmosphere and of the ocean (GCM) data. MAGICC/SCENGEN 4.1. software has been used for this purpose.

Experiments demonstrated that to minimize the uncertainty of regional climate scenarios, it is reasonable to average the output results of a number of models. Outputs of six models: CGCM1-TR, CSIRO-TR, ECHAM4, HadCM3, CCSR-NIES, GFDL-TR were averaged (multimodels approach).



Hydrological models: from run-off formation models to assessment of water resources models

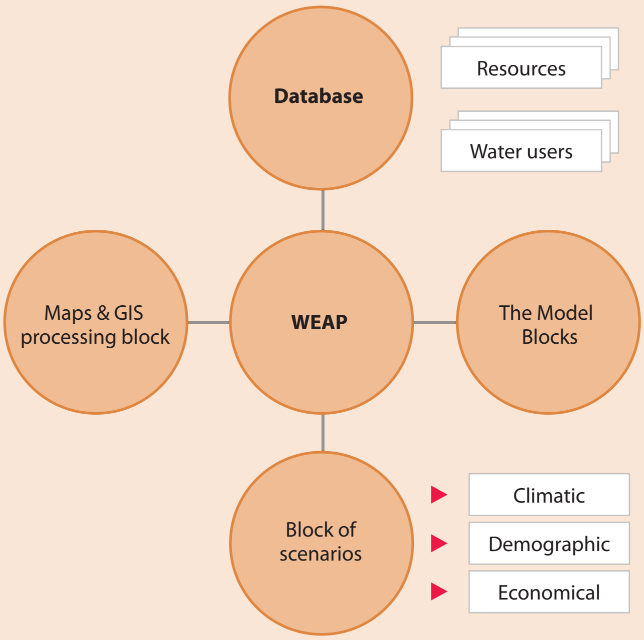
The rate of impact of the expected climate changes on the rivers' regime in the region can be evaluated with the help of the reliable mathematical models of run-off formation (AISHF). The basic mathematical model (AISHF) describes the complete cycle of the run-off formation when taking into consideration the main factors and processes such as precipitation, dynamics of snow cover, evaporation, contribution of melting and rainwater to the catchments, glacial run-off, run-off transformation and losses in basin. The model in its whole consists of a model of snow cover formation for the mountainous parts of the basin, a model of glacial run-off, a transformation model of the snowmelt and rain inflows.



WEAP Model for assessment of the water supplies and water consumption for zone of run-off dissemination (intensive use of run-off)

An integrated approach using the Water Evaluation and Planning System (WEAP) was performed for the long-term assessment of water supplies and water consumption change, based on development scenarios and focused on assessment of the following factors:

- Future climatic changes;
- Socio-economic development scenarios with consideration of various options of demographic dynamics in the country;
- Agricultural water consumption with consideration of cultivated crops composition and their areas;
- Environmental requirements;
- Destabilizing factors.



Source: Uzbekistan 2008. Second national communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change. Available online at: http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=6568

Box 22: Scenarios and Modelling for Climate Change Impacts Assessment on Water Resources in Belarus

To make future climate projections in Belarus two approaches have been used in developing future climate scenarios: computer modelling and regional analysis of historical data. Depending on the scale of the projection (Belarus as a whole, or two internal sub-regions), the regional analysis has been carried out also using data from the European part of the Russian Federation and Poland (for the projections for Belarus as a whole), and data from the Baltic Region and from the Ukrainian Pole'sie (to analyze internal differences between northern and southern subregions in Belarus).

Based on an analysis of existing assessments of possible climate change impacts the following scenarios were considered:

Scenario 1 mean annual air temperature increases by 2°C compared to the current level with the precipitation remaining unchanged;

Scenario 2 annual precipitation reduces by 10 per cent with air temperature remaining unchanged;

Scenario 3 annual precipitation reduces by 10 per cent, while mean annual air temperature rises by 2°C;

Scenario 4 Degree of peat formation (through drainage) and percentage of forestry area (through felling) in the watershed area are reduced, and the river network density (building irrigation and drainage canals) and percentage of tilled area (intensive cultivation of new agricultural land) increase by 5, 10, 20 and 30 per cent of current levels, with climatic conditions remaining unchanged.

On the basis of these scenarios, an assessment of the possible change in Belarusian water resources was done based on two methods: statistical and water-balance.

The change in water resources caused by anthropogenic warming is expressed below in relative values – in percentages against the current level.

It was calculated that a 5 per cent precipitation reduction may lead to a reduction in mean discharge by 4.5–8 per cent over the hydrological year, while a 10 per cent precipitation reduction may lead to a run-off reduction by 7–16 per cent. Increasing air temperature, with precipitation remaining unchanged, slightly reduces the run-off (3 per cent).

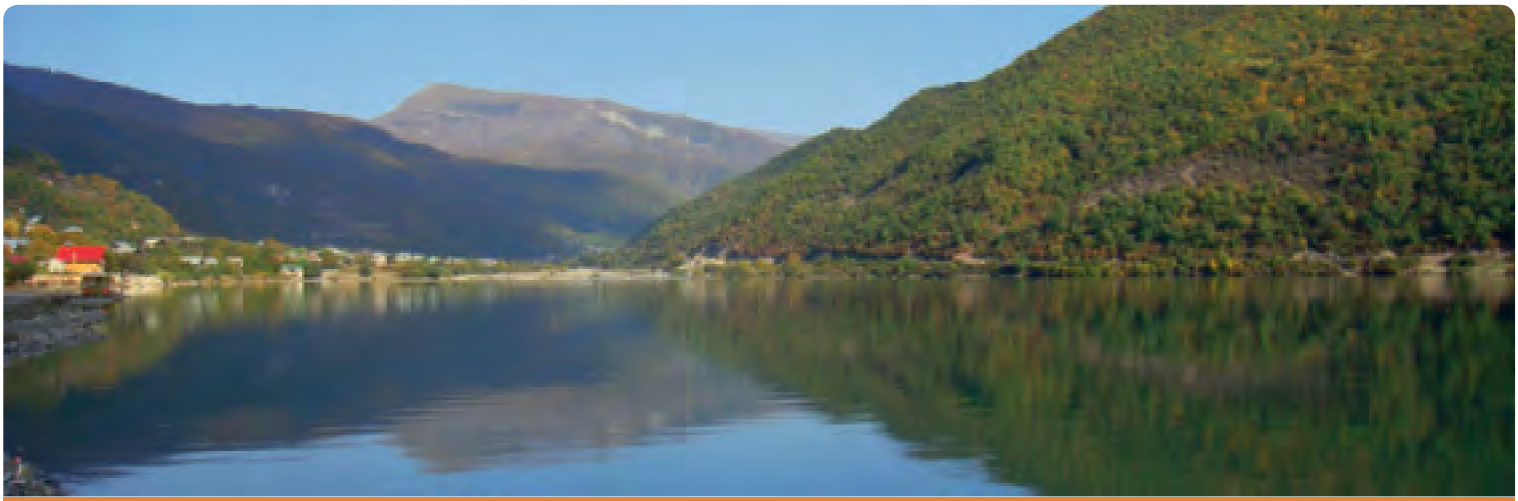
Taking into account an increase in temperature by 2° C and a simultaneous reduction in precipitation by 10 per cent leads to a reduction in river run-off by 13–14 per cent. The scientific forecast indicates that a maximum reduction in river run-off of 45 per cent may be expected in the south of Belarus. This region needs much attention when developing adaptation measures.

To minimize uncertainty in these projections, the models have been calibrated using historical data (temperature, precipitation, run-off). The operational Belarus Hydrometeorological observation network also provides continuous data to check the consistency of the models' outputs for future projections. The overall uncertainty is therefore mainly due to the uncertainty of the climate change scenarios under consideration.

Source: Central Research Institute for Complex Use of Water Resources, Belarus

effective operation of a conceptual model require reliable, accurate, consistent, and sufficiently long data sets that include the necessary observations. Input data for operation of a model may come from observations and/or output from other models, such as the climatic data coming from downscaled GCMs. By using observation data rather than model output, uncertainties inherent in the modelling procedure, such as simplifying assumptions and concepts, are avoided.

Hydrological cycle simulation models should be developed to study how climate change will modify water resources in natural regimes (see boxes 21 and 22). Other models should be developed to know how water demand (for irrigation, urban supply and industry) and available resources in water management systems will be affected and how this will affect the ecological status of water bodies. Applied models should be evaluated and revised with regard to the previous approach and in accordance with new technologies, the real impact of the driving forces, and any other changes which influence the model structure itself.



Box 23: Cooperation in the Caucasus on Climate Change Scenario Elaboration

During the process of preparation of their Second National Communications to the UNFCCC, three Caucasus countries (Armenia, Azerbaijan and Georgia) performed several runs of the PRECIS Regional Climate Model for different socio-economic scenarios and two Global Climate Models, HadAM3P and ECHAM4, to evaluate future climate in the region. This regional implementation process (Turkey, the Russian Federation and the Islamic Republic of Iran are also involved in the process) was organized and directed operationally by the Hadley Centre for Climate Prediction and Research in the United Kingdom, which has developed PRECIS and which provided it to participating countries free of charge. It also organized capacity-building workshops for national experts from implementing countries and is supporting them online. The Centre prepared the domain and boundary conditions for the region as well. Each country has performed several runs of the model: Georgia – ERA Baseline and ECHAM4 B2 2020-2050 runs, Azerbaijan – ECHAM4 Baseline, ECHAM4 A2 2020-2050 and ECHAM4 A2 2070-2100 runs and Armenia (with Hadley) – HadAM3P Baseline and HadAM3P A2 2070-2100 runs. The countries exchanged data and eventually each obtained more information than would have been possible if one country alone had applied the model. Each country validated the baseline data obtained for their territory and used it to develop climate scenarios and use parameters in climate change impact assessment studies.

However, the future climate scenarios have not yet been compiled and agreed at the regional level. It is suggested this should be done under the planned Regional Climate Change Study for the South Caucasus Region financed by the Environment and Security Initiative (ENVSEC, http://www.envsec.org/). In the framework of the study the three participating countries will develop common climate scenarios for the whole of the Caucasus region based on the research already completed under their Second National Communications Projects.

Reference: The PRECIS Regional Climate Modelling System - http://precis.metoffice.com/

5.4 Scenarios and modelling in the transboundary context

Cooperation by riparian countries plays an essential role in the success of climate change impact assessment for transboundary river basins. In a transboundary situation, agreement should be reached on the models to be used and on a common scenario or set of scenarios on which the modelling should be based. This supports developing and streamlining a common understanding between riparian countries on the effects of climate change. This in turn will support the development of joint adaptation strategies for the benefit of all concerned parties.

Studies of the regional impacts of climate change must develop credible climate change scenarios as input for regional impact assessments. Regional models provide high resolution information but are computationally very expensive. These high costs mean only a limited selection of global climate models and greenhouse gas emission scenarios can usually be considered in the context of one country. However, it is preferable to consider a range of emission scenarios in climate impact studies and the use of multiple climate models allows a better representation of the uncertainties and range of possible outcomes. Common scenario development by neighbouring countries can therefore mean a more rational use of limited resources and lead to better results for all riparian countries (see, for example, box 23).

The use of different scenarios and GCMs by neighbouring countries could lead to differences in climate and impact projections, possibly leading to contradictory adaptation measures. Combined efforts on regional downscaling of different global climate models, validating results against observed data, and agreement on model selection and greenhouse gas emission scenarios will result in more credible climate change scenarios for the whole region and reduce the uncertainties.

A systematic approach is required to test and improve data used in modelling. Hydrological models need to be set up for a particular catchment at a resolution appropriate for modelling, and their parameters should be calibrated on the basis of quality-controlled data from a number of locations collected over a period of time. It is essential to have local data to improve the results of the analysis and to calibrate the models. Regional cooperation to provide real-time or near real-time quality-controlled data from meteorological and hydrological organizations is essential for the success of such efforts. In transboundary basins, riparian countries should cooperate and agree on basic findings and approaches to clarify the basin-wide hydrological cycle. For this purpose, where data appears to be insufficient, agreed model results could be used. This could form the basis of future policies on water sharing and management.

Chapter 6

Vulnerability Assessment for Water Management

Current and future vulnerability assessments are needed for effective adaptation.

Vulnerability to current conditions can, in general, be assessed on the basis of information that is currently available, while assessments of future vulnerability require more sophisticated modelling.

The relevant stakeholders should be involved in the vulnerability assessment to improve its quality and in the development of adaptation measures to enable successful implementation.

In the transboundary context, vulnerability assessments should be developed with the participation of all riparian countries to create a common understanding of the vulnerabilities in the whole basin.

This chapter aims to help decision-makers assess the socio-economic and ecological vulnerability in a transboundary basin. Vulnerability assessments (VAs) provide decision-makers with information that guides choices on where, when and how to intervene. VAs should be undertaken by interdisciplinary teams representing natural, social and economic sciences etc., authorities and stakeholders to fit the local situation. They are based on current conditions combined with scenarios and model outcomes, and are the first steps to a better understanding of the potential impacts of climate change, a move to more effective and adaptive water resources management, and, finally, to climate proofing. Assessment of vulnerabilities can include vulnerabilities without and with adaptation (residual vulnerabilities).

6.1 Vulnerability

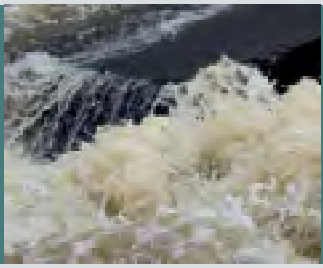
The vulnerability of a system includes both an external dimension, represented by its exposure to climate change and variability, and an internal dimension, represented by its sensitivity to these factors and its adaptive capacity. A highly vulnerable system is one that is very sensitive to modest changes in climate, where the sensitivity includes the potential for substantial harmful effects, and for which the ability to cope is limited. Thus, in a transboundary basin, the vulnerability may be different for different riparian countries, even if the risks are similar. An adaptation strategy consequently aims at reducing the vulnerability, which includes increasing the adaptive capacity.

It is necessary to distinguish between current and future vulnerability. Current vulnerability relates to current climate variability, independent of future changes in climate, and the ability of the system to cope with this variability. Current vulnerability also describes the ability of the current water management system to cope with hydrological variability. Assessing current vulnerability provides important insights into the potential responses of the system to future events. Future vulnerability relates to future climate conditions and coping ability under a situation with a changing baseline and more severe and frequent extreme events.

Many water management systems would benefit from adaptation measures that increase their resilience to hydrological variability in the current climate. Planning those measures should take into account future vulnerability. Measures taken to increase current coping ability are likely also to reduce future vulnerability.

Vulnerability has not only physical aspects but also geographical, social, economic, environmental and psychological aspects that need to be taken into account. Physical vulnerability refers to a level of susceptibility of the environment and may be described as "exposure". Geographical vulnerability relates to the geographical position of an area in a basin. A downstream country, for instance, may be more vulnerable because it has no possibility of influencing water management upstream, but in other cases upstream countries may be more vulnerable because of climatic or economic conditions. Transboundary consultation and cooperation is consequently imperative in analysing and reducing vulnerability.

The social vulnerability of peoples' livelihoods is determined by how weak or strong the livelihoods are or feel they are, how good their access is to a range of assets like financial, social (education), infrastructural (transport, communication) and ecological (ecosystem services)



assets, that provide the basis for their livelihood, and how successful different institutions are in providing social protection. Socio-economic factors can make people and societies more or less vulnerable to climate change, and also alter their perception of their vulnerability. Moreover, differences may exist in social vulnerabilities in different riparian countries. Social vulnerability can be reduced by improving factors like levels of literacy and education, health infrastructure, the existence of peace and security, access to basic human rights, systems of good governance, social equity, traditional values, customs and ideological beliefs and overall collective organizational systems.

Economic vulnerability relates to levels of individual, community and national economic reserves, levels of debt and the degree of access to credit, loans and insurance. People less privileged by class, ethnic minorities, the very young and old, those disadvantaged in a range of ways are characterized by higher economic vulnerability as they suffer proportionally larger losses in disasters and have limited capacity to recover. Similarly an economy lacking a diverse productive base is generally more vulnerable to climate disasters, in the sense that it is less likely to recover from disaster, which may lead to migration. Economic vulnerability can be reduced by improving access to critical basic socioeconomic infrastructure, including communication networks, utilities and supplies, transportation, water, and sewage and health care facilities.

Environmental vulnerability refers to the extent of natural resource degradation. Contaminated air and water and inadequate sanitation increase vulnerability. Diminished biodiversity, soil degradation, water scarcity and low water quality threaten food security and health.

Vulnerability should also be assessed at the individual level. The psychological effects of surviving traumatic climate events can persist long after physical scars have healed. This is especially true for vulnerable groups with no or very weak social support systems (e.g. elderly people living in virtual social isolation).

Some human activities can increase vulnerability to climate change and should be avoided. For example, allowing further residential and commercial development on riverine flood plains subject to inundation substantially increases the likelihood of damage by climate change.

Natural systems in different basins will respond differently to the same degree of climate change, depending largely on catchment physio-geographical, hydrological and hydro-geological characteristics, such as the amount of lake or groundwater storage in the transboundary catchment. VAs should therefore be performed on the basin level.

Many transboundary basins that are already stressed by non-climatic drivers are likely to become more stressed because of their vulnerability to climate change. Of particular relevance is the vulnerability to climate change of costly water infrastructure (e.g. dams, dykes, water intakes and pipelines), which have to serve for decades but were designed on the assumption of unchanging climatic conditions.

Ecosystems are able to adjust to some level of change in a process called autonomous adaptation. A key issue is whether ecosystem resilience will be sufficient to tolerate very rapid future anthropogenic climate change, combined with other stress factors such as population growth, changes in consumption patterns, and increased poverty. In any case, climate change will alter the functioning of ecosystems and their ability to supply the services on which society depends.

Environmental systems tend to respond to external changes in a gradual way until they cross some threshold or tipping point. Then change becomes sudden rather than gradual and may cause irreversible environmental and societal dislocation, such as species extinction or the disappearance of an island. The change leads to a transition to a new state. The existing rate of change is therefore not an indicator for the severity of the potential change. Moreover, there is a strong possibility of such sudden changes surprising societies that had been prepared at best for a gradual growth in known impacts. So the possibility of tipping points in transboundary basins should be assessed in VAs.

Depending on the subsurface characteristics, the effects of climate change on groundwater resources can be either immediate or long-delayed. Those characteristics should therefore be assessed and included in vulnerability assessments.

Box 24: Complex Assessment of Climate Change Impact on Water Resources in the Marmarik River Basin, Armenia

The Marmarik River basin is locked between mountains and flows, on average, at an altitude of 2,300 m above sea level. The basin's relief is typical mountainous with very fractioned valleys and gorges. The river's length is 37 km and its catchment basin's area 427 km². The river is fed by melting snow (55 per cent), rain (18 per cent) and groundwater (27 per cent). It is the biggest tributary of the Hrazdan River.

To assess the changes in actual river flow data were collected at three points between 1991 and 2007. The vulnerability of the water resources of the basin was analyzed, assessed and mapped for 2030, 2070 and 2100. To make prognoses, the regional PRECIS model for atmospheric circulation according to the IPCC A2 emissions scenario was used as well as a statistical or regression model and a model created with the ArcGIS software application. Starting from the baseline (1961–1990) amounts of snow precipitation, projections of expected change showed a decrease in run-off for the basin of 7 per cent (24 mm) by 2030, 21 per cent (45 mm) by 2070 and 30 per cent (64 mm) by 2100.

The reduction in water availability in the Marmarik River basin mainly affects hydro-energy production and irrigation. Energy generation is expected to decrease and possible adaptation measures relate to increasing energy prices, investigating the use of renewable energy sources, the creation of new energy-generating facilities or on building networks to connect to already functioning energy-generating facilities.

Selected measures include:

- Seasonal regulation of the river flow through dam construction along with water impoundment and underground reservoirs;
- Moisture accumulation in irrigated fields through retention of snow or snowmelt waters;
- Changing agricultural practice, including sowing alternative crops in early spring, using deepened watering furrows for moisture accumulation, and use of polyethylene cover;
- Replacing crops with a relatively high demand for water with drought-tolerant crops;
- Implementing relevant agritechnical measures and irrigation types, reducing leakages in irrigation, applying water-saving technologies.

Pilot schemes may be implemented in the Marmarik River basin to test efficient water use measures and moisture-retention methods, including increasing forest cover through afforestation and introducing new water-saving technologies.

Source: Complex Assessment of Climate Change Impact on Water Resources in Marmarik River basin, Republic of Armenia, developed under UNDP/GEF Project "Enabling Activities for Preparation of Second National Communication of Armenia under UNFCCC".

6.2 Vulnerability assessments

6.2.1 Defining vulnerability assessment

A VA delineates the specific places, human groups, sectors and ecosystems that are at highest risk, the sources of their vulnerability, and how the risk can be diminished or eliminated. So identifying the regions and people at greatest risk and assessing the sources and causes of their vulnerability is critical for designing and targeting adaptation. This shows the priorities for adaptation and helps policy-makers at various levels to decide where and when to intervene.

VAs should visualize what might happen to an identifiable population, sector or ecosystem in the current situation (current vulnerability) and under the changing conditions projected by scenarios and models (future vulnerability). VA should also cover the probability of these harmful effects.

VAs should cover both physical and social aspects. Examples of the former include land use and risk to infrastructure, including the water supply and health system infrastructure. Social aspects include personal behaviour, differences in liability coverage (e.g. state disaster management funds, obligatory individual insurance coverage), reserves for safeguarding human life, and the recovery of critical infrastructure, including health systems.

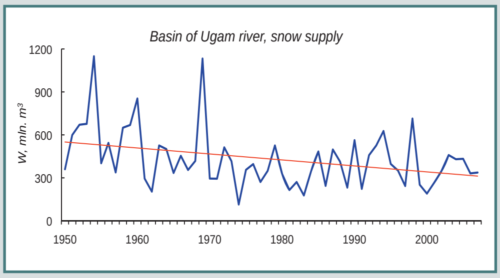
VAs are part of the ongoing process of developing an adaptation strategy and should therefore be undertaken regularly. Initially the VA focuses on the vulnerabilities of the current situation, identifying immediate priorities. Next it should focus on vulnerabilities expected after adaptation measures have been taken, to assess which measures would need strengthening. Over time, with changes taking place and insights growing, the VA is repeated to assess current and projected future vulnerabilities.

Box 25: Assessment of Water Resources Vulnerability in Uzbekistan in the Aral Sea Basin

1. Assessment of Water Resources Vulnerability in the Zone of Run-off Formation

REDUCTION OF THE MAIN SOURCES FEEDING MOUNTAIN RIVERS: MELTING OF SEASONAL SNOW COVER; GLACIERS' LONG-TERM CAPACITY

Reduction of snow supplies is identified in the mountain river basins



Glaciers continue to reduce at a rate of about 0.2 to 1 per cent per year

Reduction of available water resources. Expected reduction of water resources up to 2050: for the Amu Darya river basin -10 to -15 per cent; for the Syr Darya river basin -2 to -5 per cent. Run-off assessment under climate change depends on the models, scenarios and methods

2. Assessment of Water Resource Vulnerability in areas of intensive water use

- Water consumption increase in industry, municipal sectors and potable water supply

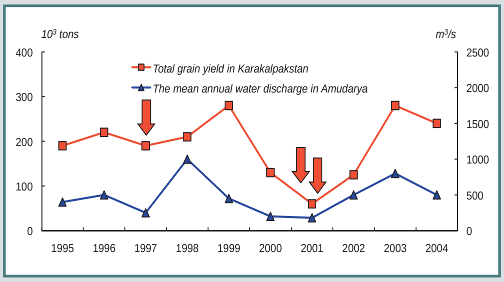
  The assessment showed that the total water deficiency in Uzbekistan will possibly rise to 7 km³ by 2030, and by 2050 to 11–13 km³, when implementing IPCC climate change scenarios A2 and B2.

- With an increasingly dry climate and an unchanged system of water resource management, river water is likely to become more saline. Potable water quality will significantly deteriorate both up- and downstream in the Amu Darya River.

- The peak of acute intestinal infection incidence occurs in the warm period of the year, from May to October-November for all regions of Uzbekistan. An assessment demonstrated that potential risk of acute intestinal infections will increase by 8–10 per cent by 2050 and 15–18 per cent by 2080 due to expected increase in temperature.

WARMING CONSEQUENCES FOR IRRIGATED FARMING IN UZBEKISTAN

Increase of irrevocable losses in irrigation areas



Water consumption increase in irrigated farming and other water uses (evaporation)

- growth of irrigation water deficiency;
- intensification of irrigated land salinity;
- more frequent air drought as well as extremely high temperatures; resulting a.o. in reduction of yield power of modern agricultural crop varieties

A decreased flow in the Amu Darya and Syr Darya rivers will aggravate the Aral Sea crisis.

Source: Uzbekistan 2008. Second national communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change. Available online at: http://unfccc.int/essential_background/library/items/3599.php?rec=j&priref=6568

Box 26: The Climate Vulnerability Index

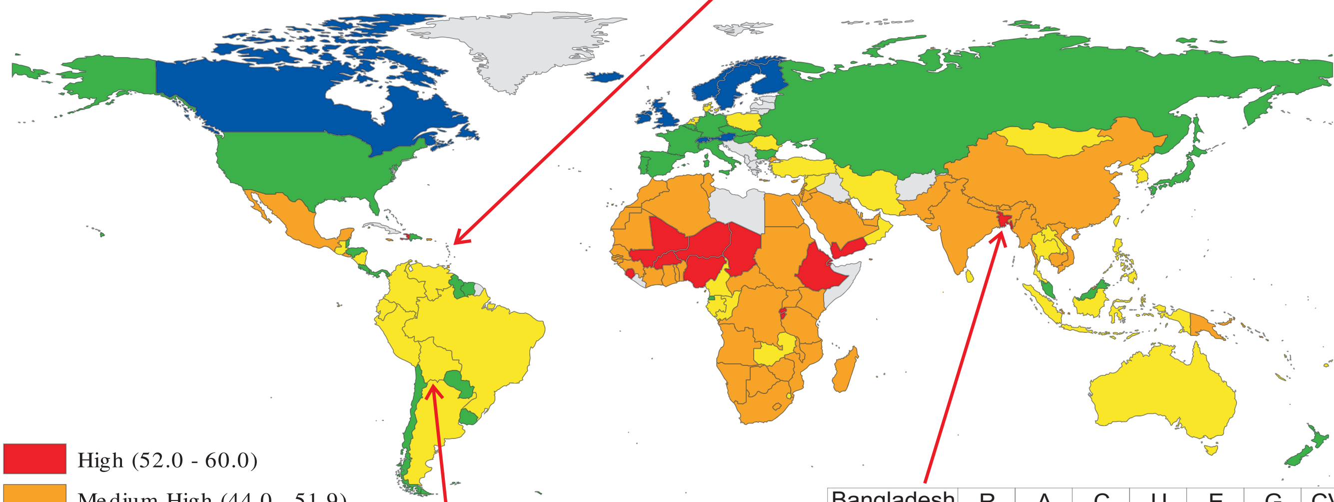
People's vulnerability to global changes depends on a combination of factors. In terms of water resources, that vulnerability is not only influenced by the quantity of water that is available now and in the future, but also by a range of social, economic and environmental factors which will affect the ability to cope with changing conditions. To capture the essence of this definition of vulnerability, a composite index approach is proposed (as used in the construction of the Human Development Index). This could explicitly incorporate indicators which represent the diverse dimensions of risks which give rise to vulnerability within a population, and this has been incorporated into a method of assessment known as the Climate Vulnerability Index (CVI). The objective of this method is to help to identify those areas which are most vulnerable, in order to prioritise specific actions to protect local populations. The table below shows the major Global Impact Factors of the CVI and suggested indicators to represent them. The map illustrates the variability of CVI values across the world.

Major Global Impact Factors of the Climate Vulnerability Index approach and potential variables which may be selected for inclusion as sub-components of the Index.

GLOBAL IMPACT FACTORS	DESCRIPTION	POTENTIAL SUB-COMPONENTS OR VARIABLES
Geospatial (G)	Includes a number of geographical factors which relate specifically to the place being examined.	Extent of land at risk from sea level rise and/or tidal waves Extent of land at risk from land slips Degree of isolation from other water resources and/or food sources Deforestation, desertification and/or soil erosion rates Degree of land conversion from natural vegetation Extent of risk from melting of glaciers, and the risk of glacial lake outbursts
Resource Quantification (R)	The physical availability of surface and groundwater, taking account of the variability and quality of the resource as well as the total amount of water.	Assessment of surface water and groundwater availability Evaluation of the reliability of resources Assessment of water quality Dependence on imported or desalinated water Water storage capacity
Accessibility and property rights (A)	The extent of access to water for human use, accounting for not only the distance to a safe source, but the time needed for collection of a household's water and other significant factors. Access to water for irrigating crops and industrial use is also included.	Access to clean water Access to sanitation Access to irrigation coverage adjusted by climate characteristics
Capacity of people and institutions (C)	The effectiveness of people's ability to manage water. Capacity is interpreted in the sense of income to allow purchase of improved water, and education and health which interact with income and indicate a capacity to lobby for and manage a water supply.	Expenditure on consumer durables, or income Under-five mortality rate Existence of disaster warning systems Educational level of the population Percentage of people living in informal housing GDP as a proportion of GNP Strength of municipal institutions Investment in the water sector as a percentage of fixed capital investment Access to a place of safety in the event of flooding or other disasters
Utilization (U)	The ways in which water is used for different purposes; includes domestic, agricultural and industrial use.	Domestic water consumption rate related to national or other standards Agricultural water use related to the contribution of agricultural production to GDP Industrial water use related to the contribution of industrial production to GDP
Ecological integrity maintenance (E)	Tries to capture an evaluation of ecological integrity related to water.	Loss of habitats Human population density Livestock density Flood and drought frequency

Global Climate Vulnerability Index Values for 2000, with Illustrations of Potential Change

Examining Potential Change using the CVI
Illustrating change in future component values



Barbados	R	A	C	U	E	G	CVI
2000	67.8	0.0	10.2	46.3	45.6	35.8	34.3
2030	78.5	0.0	8.8	53.6	53.2	35.8	38.3

Bangladesh	R	A	C	U	E	G	CVI
2000	55.1	31.0	49.6	38.3	55.2	76.7	50.1
2030	64.0	7.8	33.7	50.7	78.0	86.8	53.5

Bolivia	R	A	C	U	E	G	CVI
2000	32.1	26.3	42.0	42.9	43.2	54.7	40.2
2030	47.5	6.6	28.4	61.0	50.4	59.7	42.3

- High (52.0 - 60.0)
- Medium High (44.0 - 51.9)
- Medium (36.0 - 43.9)
- Medium Low (28.0 - 35.9)
- Low (20.0 - 27.9)
- No Data

Source: Caroline Sullivan, created for the Guidance

The value of the CVI is a weighted average of all the Global Impact Factors. In practice, determination of the value of weights to be applied to an index such as the CVI should be achieved through participatory consultation with local stakeholders and expert opinion, or as a result of statistical analysis, such as an examination of the probabilities of risk of various impacts.

The resulting CVI scores give a measure of vulnerability to existing climate variability at the present time, and allow comparisons to be made between different locations. The index values range from 0 to 100, with high values indicating high vulnerability. By applying scenarios of future conditions, both on climatic conditions as well as socio-economic scenarios, the change in the CVI scores from the present values will indicate how different Global Impact Factors of the CVI will change under new conditions. This will help to highlight how climate and other global changes will impact on the selected aspects of human lives represented by the CVI. This approach therefore provides a consistent and transparent methodology for the comparative assessment over both time and space of the vulnerability of human populations to the impacts of climate change on water resources.

RELEVANCE OF THE CLIMATE VULNERABILITY INDEX

A distinctive feature of the CVI is its applicability at a range of spatial scales (and it can be applied at finer resolutions in order to reflect the true spatial variability of vulnerability) and the social and environmental issues relating to it, depending on the resolution of available data. One of the major features of this approach is the fact that it starts with the conditions of human wellbeing, and assimilates various disciplines to eventually include information at the largest scale, that relating to climate change. In comparison with other approaches, the CVI is closer to a "bottom up" approach and has much more potential for involvement of stakeholders especially under conditions of uncertainty in both the biophysical and socio-political spheres. In contrast to this, other climate vulnerability approaches tend to move from large scale climate models downwards toward the people, in spite of the acknowledged uncertainties both in climate models, and in the process of downscaling model results.

References:

Sullivan, C.A., J.R. Meigh and M.C. Acreman, 2002. *Scoping Study on the Identification of Hot Spots – Areas of high vulnerability to climatic variability and change identified using a Climate Vulnerability Index.* Report to Dialogue on Water and Climate, CEH Wallingford, United Kingdom.

Sullivan C.A. and J.R. Meigh, 2005. Targeting attention on local vulnerabilities using an integrated indicator approach: the example of the Climate Vulnerability Index. *Water Science and Technology,* Special Issue on Climate Change 51 (5): 69–78.

Sullivan, C.A. and C. Huntingford 2009. *Water Resources, Climate Change and Human Vulnerability.* Paper presented to the 18th World IMACS / MODSIM Congress, Cairns, Australia 13–17 July 2009.

6.2.2 Methodologies for vulnerability assessments

There is no "one-size-fits-all" VA methodology. VAs should be adjusted to the purpose of the assessment and should be tailor-made for the water management objectives or water services of a particular basin (see as examples boxes 24 and 25). Typically, a VA includes the following steps:

- Formulation of scope and structure of the VA as well as the definitions used. In a transboundary context, the riparian countries have to agree upon the scope of the study but also on the definitions to be used. This step includes defining the objectives of the VA, identification of the scenarios and models to be applied, agreement upon the definitions and frameworks that are applied, and identification of the stakeholders who will guide the use of the VA;

- Identification of vulnerable groups, systems and areas of potential climate change damage. A key element in this step is defining the vulnerability indicators and critical thresholds. This choice depends on the scope of the study and the water management objectives and is needed to assess the direction and magnitude of the changes affecting the system. The outcome of this step is a set of vulnerability indicators and identification of vulnerable livelihoods (or other targets) that, together, form a vulnerability baseline of present conditions;

- Assessment of current vulnerability in terms of exposure, sensitivity and coping ability of the selected system and vulnerable groups. How resilient are the groups and areas to current stresses?;

- Assessment of future vulnerability in terms of exposure, sensitivity and coping ability of the selected system and vulnerable groups. With the use of scenarios and models, the future exposure of livelihoods and areas to climate changes is assessed;

- The outcome of the VA is a qualitative description of the vulnerability of groups and areas that provides an understanding of the situation and directions in which measures should be developed. This understanding should be used in further adaptation policy and planning.

Representatives of the systems and groups that are affected should be involved in the VA, both to improve the quality of the VA and to enable involvement of these stakeholders in the development and implementation of adaptation measures. These stakeholders are identified in the first step of the VA.

The following criteria can be used to identify the vulnerabilities of systems and groups:

- Magnitude, timing, distribution, persistence and reversibility of impacts;

- On social issues: demography, health, education and work, access to information, well-developed institutions, culture and personal wealth;

- On economic issues: infrastructure, capital value, surface area and labour force;

- On ecological issues: habitat, pollution level, ecological values and environmental pressure.

The coping ability of livelihoods and individuals can be assessed through various social, geographic and environmental parameters such as differences in health status, economic standing, level of technology, level of education, access to information, level of institutions, policies and regulations, variety of infrastructure and equitable distribution of resources. Combining such variables in development models or indices allows the making of comparisons to determine the most critical regions or hot spots (see as an example the Climate Vulnerability Index described in box 26).

Determining which impacts of climate change are potentially important and which are the most dangerous is a dynamic process involving a combination of scientific knowledge with factual and subjective elements.

Essential aspects of VAs are the integration of different scientific disciplines and integration between researchers and stakeholders. It is also important that the VA be sufficiently flexible to meet participants' needs.

VAs should include estimates of the uncertainty of the impacts and vulnerabilities and the confidence in those estimates. Furthermore, the distribution of impacts and vulnerabilities across groups should be assessed.

Box 27: Vulnerability in the Disaster Risk Community

The prime objective of the United Nations International Strategy for Disaster Reduction (ISDR) is to build disaster-resilient communities by promoting increased awareness of the importance of disaster reduction as an integral component of sustainable development. In this way, ISDR aims at reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental disasters. The Hyogo Framework for Action aims to both build up the resilience of nations and communities to disasters and integrate disaster risk reduction with climate change strategies.

The framework distinguishes five steps:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation. This includes creating effective, multi-sector national platforms to provide policy guidance and to coordinate activities; integrating disaster risk reduction into development policies and planning, such as Poverty Reduction Strategies; and ensuring community participation, so that local needs are met.

2. Identify, assess, and monitor disaster risks – and enhance early warning.

3. Use knowledge, innovation, and education to build a culture of safety and resilience at all levels. Key activities include providing relevant information on disaster risks and means of protection, especially for citizens in high-risk areas; strengthening networks and promoting dialogue and cooperation among disaster experts, technical and scientific specialists, planners and other stakeholders; including disaster risk reduction subject matter in formal, non-formal, and informal education and training activities; developing or strengthening community-based disaster risk management programmes; and working with the media in disaster risk reduction awareness activities.

4. Reduce the underlying risk factors. Countries can build resilience to disasters by investing in simple, well-known measures to reduce risk and vulnerability. For example, disasters can be reduced by applying relevant building standards to protect critical infrastructure, such as schools, hospitals and homes; vulnerable buildings can be retrofitted to a higher degree of safety; precious ecosystems can be protected, allowing them to act as natural storm barriers; and effective insurance and micro-finance initiatives can help to transfer risks and provide additional resources.

5. Strengthen disaster preparedness for effective response at all levels. Preparedness involves many types of activities, including the development and regular testing of contingency plans; the establishment of emergency funds to support preparedness, response and recovery activities; the development of coordinated regional approaches for effective disaster response; and continuous dialogue between response agencies, planners and policy-makers, and development organizations.

Many reports and guidelines published under the Hyogo framework help to develop and implement plans and programmes to reduce vulnerability.

Source: ISDR. Hyogo Framework for Action 2005-2015. Available online at: www.unisdr.org/hfa.

Chapter 7

Adaptation Strategies and Measures

Adaptation strategies and measures should be based on the results of vulnerability assessments as well as on development objectives, stakeholder considerations and the resources available.

If little or no information is available for structured vulnerability assessments, adaptation should be based on available general information combined with expert and local knowledge.

Effective adaptation strategies are a mix of structural and non-structural, regulatory and economic instruments, and education and awareness-raising measures to tackle short-, medium- and long-term impacts of climate change.

Given the uncertainty associated with climate change, win-win, no regret and low regret measures should be chosen as a priority.

There is a need to adopt a cross-sectoral approach when formulating and evaluating options. In this respect, SEA is a useful tool.

In transboundary basins, cooperation between all riparian countries is needed to design effective strategies.

Adaptation strategies consist of a broad plan of action to be implemented through policies and measures over the short-, medium- and long-term. Measures should focus on actions aimed at specific issues. Measures can be individual interventions or they can consist of packages of related measures. This chapter aims to support decision makers in planning and implementing such strategies and measures.

The results of vulnerability assessments should be the basis for planning and implementing adaptation strategies and measures. Nevertheless, if little or no information is available to perform a structured vulnerability assessment, adaptation strategies and measures should be based on generally available global or local information, like predictions of changes in hydrology, combined with expert and local knowledge.

The objectives of a strategy will depend on the development objectives, stakeholder considerations and the resources available. The decision process is the responsibility of decision makers who may come from a wide variety of institutions, including national, regional and local governments and their departments, the private sector and civil society. The decision process should encourage active participation from interested groups, as this helps to minimise the risk of overlooking potential impacts, and of failing to identify mal-adaptation. It should also ensure that differences in the perception of risks and values are fully explored within the risk assessment and decision appraisal process.

To be successful, any adaptation strategy should include measures covering all the steps of the adaptation chain: prevention, improving resilience, preparation, reaction, and recovery. Measures for prevention and improving resilience are related both to the gradual effects of climate change and to extreme events. Preparation, response, and recovery measures are chiefly relevant for extreme events such as floods and droughts. As there is a continuum of adaptation measures, it is not always feasible to categorize certain measures as one specific type (see table 3).

Measures can vary greatly and are usually a mix of, among other things, structural and non-structural, regulatory and economic instruments, and education and awareness-raising (see section 3.5) measures. Currently, many adaptation strategies mainly focus on structural aspects, such as protective dams. However, non-structural measures should also be considered, such as measures that inform and influence behaviour and capacity-building activities.

The portfolio of policies and measures should be designed on the basis of a thorough consideration of costs and benefits, and aiming to ensure that measures complement and reinforce one another.

Climate change effects occur at different time scales (see section 7.2 below), while catastrophic events occur at comparatively short time scales. Many effects of climate change occur at longer timescales and will be better understood as more information becomes available. Thus there will never be one definitive and final set of measures. Rather, measures will need to be developed to address the effects that pose the highest risk to human health first, and efforts will continuously need to be made to better understand ongoing climate change and to develop appropriate adaptation measures to new risks as they become better understood.

The capacity to adapt requires flexibility. As a result, measures that are highly inflexible or where reversibility is difficult should be avoided.

In most situations, adaptation is likely to occur through autonomous actors as individuals, households, businesses and communities respond to the opportunities and


constraints they face (“autonomous adaptation”). While “planned” approaches based on vulnerability assessments are important, it is equally important to understand and enable the adaptive responses that are occurring in an unplanned manner within society. Education and capacity-building are very important not only to promote adaptive responses but also to prevent adverse effects of autonomous adaptation measures. For example, in drought-prone regions, individuals might “adapt” by using more water for irrigation or by drilling their own wells, which can however only aggravate the situation by reducing overall water availability.

In transboundary basins, riparian countries should discuss and agree on where and when and which different measures need to be taken so as to maximise their impacts on all the countries involved.

7.1 Types of measures[16]

Measures include legislative and regulatory instruments (e.g. laws, by-laws, regulations, standards, constitutional guarantees, and agreements based on international conventions); financial and market instruments (e.g. concessions, licences, permits, taxes, payments for amenities, user fees, tax credits for investment funds, performance bonds, labelling, procurement policies, product certification, and information disclosure requirements); education and informational instruments (e.g. consumer information, public awareness campaigns, and professional development); and policy instruments (e.g. environmental management systems, management policies, etc.). They can include developing new measures, changing current management practice, and decommissioning existing structures that increase vulnerability.

Prevention measures are taken to prevent the negative effects of climate change and climate variability on water resources management. Prevention measures are based on risks, hazards and vulnerability maps under different scenarios. To support them, projections are needed both on a medium- and long-term basis.

Prevention measures can include, for instance, the minimization or complete prevention of urban development in flood-prone areas or development and implementation of water-efficient methodologies in water-dependent sectors (such as agriculture, industry), but also measures to improve the retention of water such as wetland restoration/protection or afforestation which also help to prevent landslides and land degradation. Prevention measures may be targeted to long-term developments (for example afforestation or wetland restoration/protection), to medium-term developments (for example reduction in water use in industries and agriculture) and short-term developments (for example population migration from flood-prone areas), but are often of a long-term nature.

Where the threat of climate change makes continuation of an economic activity impossible or extremely risky, consideration can be given to changing the activity. For example, a farmer may choose a more drought-tolerant crop or switch to varieties with lower moisture. Similarly, cropland may be returned to pasture or forest, or other uses may be found such as recreation, wildlife refuges or national parks.

Measures to improve resilience aim to reduce the negative effects of climate change and variability on water resources management by enhancing the capacity of natural, economic and social systems to adapt to the impacts of future climate change.

Resilience is often enhanced by diversification into activities that are less inherently vulnerable to climate. Measures to improve resilience target long-term developments, such as switching to crops that are less water-demanding or are salt-resistant. Improving resilience can also be done on a short-term horizon, for instance by operating dams and water reservoirs (surface and underground) in such a way that sufficient water is retained and stored in the wet season to balance the water needed in the dry season.

Ecosystems play an important role in climate adaptation. For instance they can contribute to flood regulation by attenuating the variability of hydrological events. Forests, for instance, can retain water, thus slowing down run-off, and wetlands have a buffering effect against floods and droughts. Healthy ecosystems can thus increase resilience. Conservation and restoration of ecosystems should therefore be an integral part of adaptation strategies (see box 28).

[16] Examples of measures are included in table 3.

Box 28: Enhancing the resilience of ecosystems

Rivers are important ecosystems and it has become generally accepted that resilient rivers (with intact floodplains) can better respond to high floods and that damage is not so disastrous as along the straightened ones. Many large rivers in Europe have been facing severe floods in recent decades due to hydromorphological alterations. Implementation of measures in a river catchment can have upstream and downstream effects and therefore requires transboundary cooperation of riparian countries. Measures to alleviate floods include dyke relocations, creation of side channels, lowering of floodplains and the removal of hydraulic obstructions from floodplains. Organizations including the European Centre for River Restoration (ECRR) and the Worldwide Fund for Nature (WWF) are working on restoring floodplains.

SOFT INFRASTRUCTURE, HABITAT RESTORATION, AND FLOOD CONTROL: THE LOWER DANUBE

Conversion of floodplains for farming and other development has seen 95 per cent of the upper Danube, 75 per cent of the lower Danube and 28 per cent of the Danube delta's historical floodplains cut off by flood protection dykes for conversion to agriculture, forestry, and aquaculture use. The excision of floodplains has exacerbated flood peaks. In 2005, a flood killed 34 people, displaced 2,000, inundated 690 km^2, and caused US $625 million of damage in Hungary, Romania, Bulgaria and the Republic of Moldova. A 2006 flood displaced 17,000 people, inundated 1,450 km^2, and cost $8.6 million in Romania alone. Climate change is expected to further increase the frequency and severity of large floods.

In 2000, at the initiative of WWF, the Heads of State of Bulgaria, Romania, the Republic of Moldova and Ukraine agreed to restore 2,236 km^2 of floodplain to form the 9,000-km^2 Lower Danube Green Corridor (or LDGC) to attenuate floods, restore and protect biodiversity, improve water quality and enhance regional livelihoods. By 2008, 469 km^2 of floodplain (14 per cent of the area pledged) had been restored. Some flood control benefits are already visible, for example the restored 21-km^2 Babina Island polder alone holds 35 million m^3 of floodwater.

From a development perspective, floodplain restoration helps to improve local livelihoods. Reduced vulnerability to floods is a major benefit for communities. Most of the polders targeted for conversion were not very profitable compared with diversified strategies of fishing, tourism, reed harvesting and livestock grazing. At Katlabuh Lake, improved water quality will enhance drinking and irrigation water. Altogether, provision of ecosystem services for fisheries, forestry, animal feed, nutrient retention, and recreation through floodplain restoration is valued as €500/ha/yr. If the total pledged area in the LDGC is restored, the value of the resulting ecosystem services is estimated at €111.8 million annually. Biodiversity impacts have also been significant. At the Babina Island polder, the number of resident bird species more than doubled.

Political barriers have been encountered during the restoration process. Implementation has been slower than anticipated. Some individuals have not consented to land use shifts, and land laws have hindered progress. WWF has worked to improve stakeholder relations and has resorted to covering costs ineligible for governmental funds.

Learning from the 2005 and 2006 floods has also been important and Romania is currently completing a national floodplain restoration strategy to reduce flood risk. Patience and persistence have also been required. Implementation represents a long-term commitment. This should be taken into account by other groups considering similar projects. Linking work at local, national, basin, and European scales has been critical to achieving results.

FLOOD ALLEVIATION IN THE RHINE RIVER BASIN

Within the INTERREG programme, between 2003 and 2008 flood alleviation measures were planned and implemented along the Rhine in Germany and the Netherlands. Dutch and German partners restored former and existing floodplains in twelve pilot projects. The close cooperation has created a know-how platform for sustainable flood prevention in Europe.

One example of the partnership is the dyke relocation at Kirschgartshausen, upstream of the German cities of Ludwigshafen and Mannheim. The effects of the dyke relocation are that the flood area in this part of the river is widened and the floodplain is naturally flooded again. The measure leads to more hydro-morphological dynamics in the reconnected floodplain area and will improve the quality of the riverine nature in the mid- and long- term and improve the ecological networks along the river. Furthermore, an old channel will be reconnected to the Rhine, which will improve water quality through the restored water exchange. The channel faced a big problem of eutrophication in the last decade. Parts of the floodplain in the summer polder will still be used for agriculture. Nature will benefit from the development of natural floodplain vegetation including hardwood forests, and diverse species of fish and amphibians which depend on water and/or wetlands.

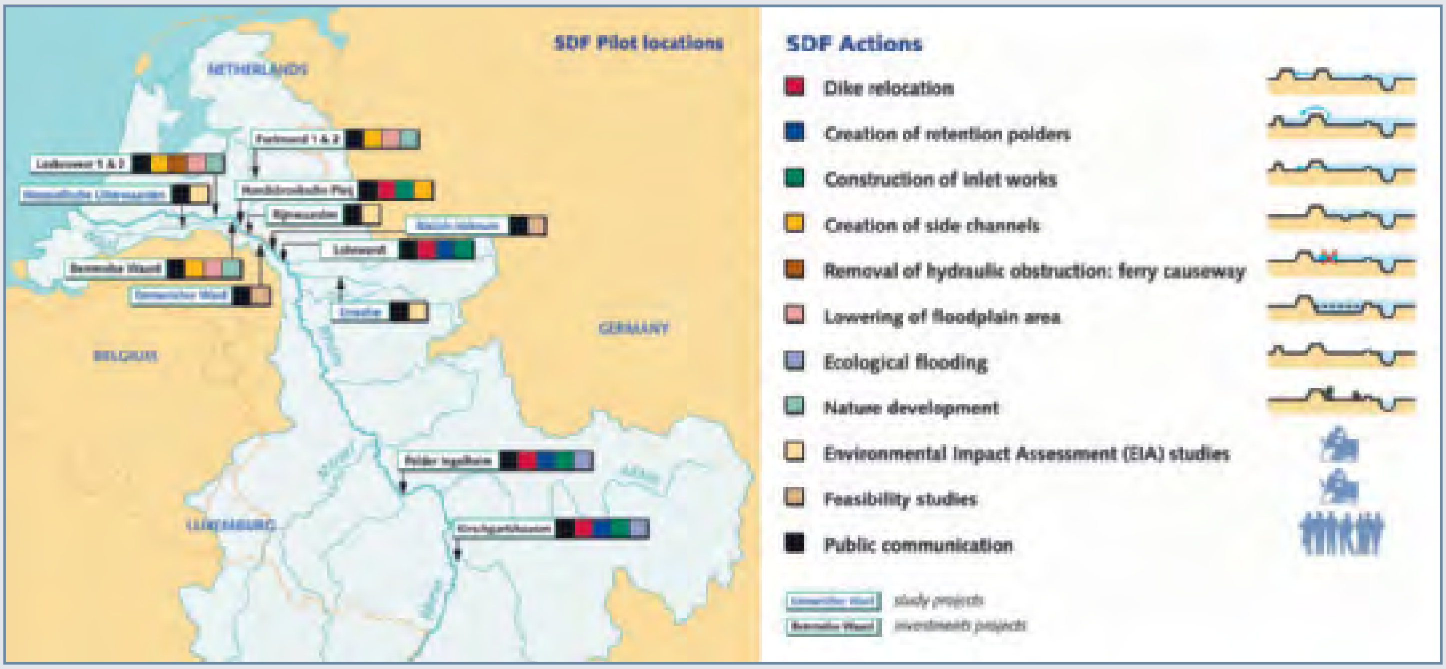
The upper Rhine area in Germany is quite densely populated and the combination of different land use interests with nature conservation or rehabilitation interests demands a clear land use strategy and/or landscape planning. A good instrument to reconcile the interests and possible conflicts over land claims is the principle of eco-accounting aimed to simplify and optimize the planning and realization of ecological compensation measures within legal procedures. Out of a landscape plan, the potentials of areas within a region are evaluated for ecological improvement measures. Areas which are appropriate and available for ecological restoration measures are transferred to a pool. As soon as an ecological restoration measure on one of these lots is realized, it can be transferred to the eco-account in form of eco-points. The sponsor of the measure or the municipality can then use these eco-points at a later date to construct environmentally unfavourable projects in another area. By offsetting in this way, the sponsor of a measure to upgrade a floodplain creates a credit for other building projects. In Kirschgartshausen, 0.15 km^2 of hardwood floodplain forest were already planted in a former intensively agriculturally used area as compensating measures for the construction of a large multi-function stadium (SAP arena) and the establishment of a large furniture company (IKEA).

References: www.sdfproject.nl.

For the Danube project: Suzanne Ebert, WWF Danube-Carpathian Programme Office, sebert@wwfdcp.org

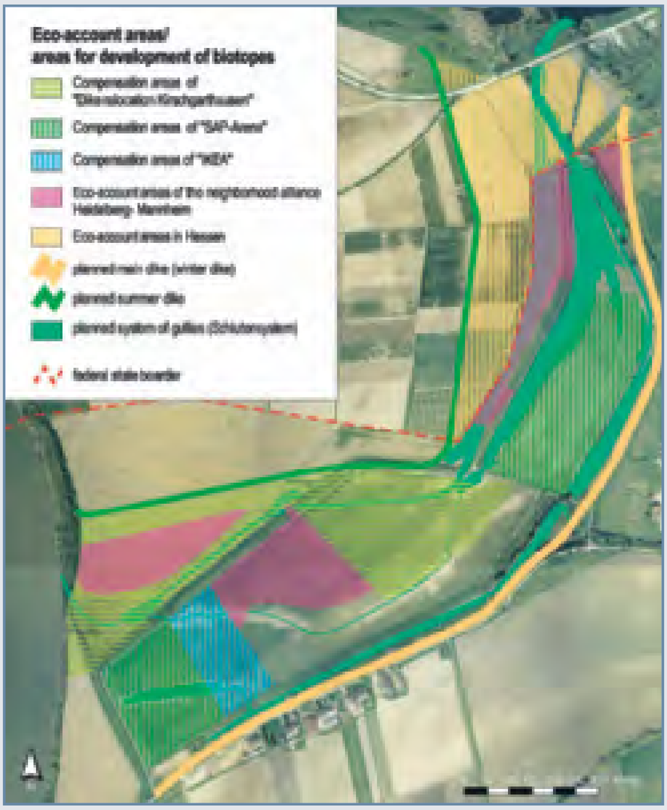
John Matthews, WWF

PILOT LOCATIONS AND ACTIVITIES



AERIAL VIEW OF THE LOCATION OF KIRSCHGARTSHAUSEN

ECO-ACCOUNT AREAS/AREAS FOR DEVELOPMENT OF BIOTOPES



Box 29: An Example of Preparation Measures – Drought Management Plans

Drought management plans (DMPs) are tools to manage water resources during droughts. They describe appropriate measures to apply according to harmonized national drought indicators and prioritise uses to protect water ecosystems facing water stress. DMPs aim to guarantee the water availability required to sustain a population's life and health, to avoid or minimize the drought's effects on water bodies, especially on environmental flows to avoid any permanent negative effects, and to minimize effects on public water supply and on economic activities, according to the priority uses set by water policies and river basin management plans.

The Spanish legal framework specifically refers to drought in the planning process, and determines measures to address droughts for public administration and stakeholders. In the past exceptional measures were applied during a crisis, but few of them dealt with preparedness, mitigation and prevention. Now, during unusual droughts, the Government may adopt exceptional measures, even if concessions (rights of water use under certain conditions) have been granted. Such measures may include the building of emergency infrastructures, as for instance drought wells. The Water Act also included the following water use priority list: water supply in urban areas, irrigation, industrial uses for power generation, other industrial uses, fish farming, recreational uses and navigation.

The experience acquired during Spain's last droughts has shown how this concept was inappropriate and demonstrated the need for new regulations and adequate drought risk management measures.

The new legal framework deals with drought planning and management through modifications introduced in the Water Act. For instance, the Government may authorize the river basin authority to set up water interchange centres (water banks) to enable user rights to be waived by voluntary agreement. The National Water Plan Act states that the Ministry of Environment must establish a global Hydrological Indicators System (HIS) and river basin authorities (Confederaciones Hidrográficas) must prepare drought plans and submit them to respective river basin councils and the Environment Ministry for approval. Municipalities should also develop emergency plans for urban water supply (for more than 20,000 inhabitants) to ensure water services under drought conditions.

The HIS was elaborated using different parameters (inflows, outflows and storage in reservoirs, flow river gauges, precipitation and piezometric levels) for each management system. In addition, a general guidance document was developed by the Ministry of Environment to facilitate the process of developing drought plans. According to this guidance, when preparing DMPs authorities should:

- Include indicators that will provide a quick drought status early enough to act according to the forecasts of the plan;
- Provide information on the resources system and its vulnerability;
- Provide knowledge of the demand system and its vulnerability towards droughts, organized by priority degrees;
- Present structural and non-structural alternatives to reduce drought impacts;
- Determine the cost of implementing measures;
- Adapt the administrative structure for the DMPs follow-up and coordination among the different administrations involved (e.g. the Ministry, regional governments, municipalities);
- Discuss plans, results and follow-ups with all interested parties, ensuring full public participation to avoid social conflicts.

Basin authorities have been able to elaborate plans according to the local situation and needs, declare the drought status according to the HIS threshold, and initiate measures included in the Plan depending on the gravity of the drought.

The main mitigation measures included in the plans can be grouped into different categories: structural measures (new pumping wells, new pipes, use of new desalination plants, etc.) and non-structural measures (water savings by applying restrictions to the users, increase in the use of groundwater, etc).

The Directorate General for Water coordinated jointly with the river basin authorities the elaboration and approval process of drought plans, which were finally launched on March 2007 after completing their SEA processes. Based on the HIS thresholds, monthly maps of the drought situation in the different management units within each Spanish basin are being developed, and can also be found in the Ministry's website since December 2005.

Source: Spanish Ministry of the Environment and Rural and Marine Affairs

Measures to enhance the resilience of ecosystems and to secure essential ecological services for human society are of high importance. These include: (a) protection of adequate and appropriate space; (b) limitation of all non-climate stresses; and (c) use of active adaptive management and strategy testing. Conservation of keystone species, planning along climate gradients (e.g. mountain altitudes), promoting connectivity (e.g. protected areas and corridors), fragmentation avoidance and protection of climate refuges with especially resistant habitats can help to conserve vital ecosystems and their habitats.

Preparation measures aim to reduce the negative effects of extreme events on water resources management. Such measures are based on risk maps under different scenarios. To support preparation measures, short-term weather forecasts are needed as well as seasonal forecasts.

Preparation measures include early warning systems, emergency planning, raising awareness, water storage, water demand management and technological developments. Preparation measures are usually established to run over a long period, but are often only active at the operational level (see, for example, box 29).

Response measures aim at alleviating the direct effects of extreme events. To support response measures, seasonal and short-term weather forecasts are needed.

Response measures include, for instance, evacuation, establishing safe drinking water and sanitation facilities inside or outside affected areas during extreme events, movement of assets out of flood zones, etc. Response measures target the operational level.

Recovery measures aim to restore the economic, societal and natural system after an extreme event. To support recovery measures, predictions are needed both on a seasonal and a long-term basis. Recovery measures include, for instance, activities for the reconstruction of infrastructure and operate at the tactical level – short term and long term – e.g. restoration of electricity supply etc. Recovery measures also include insurance, as a risk transfer mechanism.

Recovery measures do not necessarily aim at restoring the situation that existed before the extreme event. Especially when the existing systems are very vulnerable, severe damage to or destruction of the systems may be an occasion to change to less vulnerable systems. Rebuilding of houses or industries that were destroyed by floods may for instance be done in places that are less flood-prone. Destruction of crops by severe or prolonged droughts may be an occasion to change to less drought-sensitive crops or to alternative economic activities.

Especially during and after response and recovery, an evaluation should be made of the prevention, resilience improvement, preparation, response and recovery measures related to the extreme event (see, for example, box 34).

7.2 Measures at different time scales

For effective adaptation strategies, measures need to be implemented on different time scales:

- **Long-term measures** are related to decisions to address long-term (decadal) climate changes and are based on long-term projections. They usually exceed the scope of water sector planning because they affect the development model and the socio-economic background through institutional and legal changes (e.g. land use planning);

- **Medium-term measures** relate to decisions aiming at addressing medium-term (within one or two decades) climate trend projections and introducing the required corrections in the framework through hydrological planning measures such as risk management (for example drought and flood management plans);

- **Short-term measures** relate to decisions addressing identified problems mainly under the current climate, i.e. under current hydrological variability. They correspond to measures that can be adopted in the current institutional, legal and infrastructural frameworks, and usually refer to risk assessment, preparedness and vulnerability reduction (for example revised water allocations during drought).

A common problem is a focus on short-term measures. Medium- and long-term planning should be fostered, although this is often difficult due to short electoral cycles, funding constraints and the high uncertainty associated with medium- and long-term forecasts. Linking short, medium and longer term planning is necessary to ensure that, for instance, short-term measures do not counteract longer term ones.

Box 30: Preventing and Responding to Negative Health Outcomes

Health systems – comprising all organizations, institutions and resources devoted to improving, maintaining and restoring health – have the dual role of taking all necessary measures to ensure that water-related diseases linked to climate change are prevented so far as possible, and also ensuring that a system is in place to monitor the incidence of such diseases and detect outbreaks, and that contingency plans are in place to deal with such outbreaks.

Countries should take a number of actions to strengthen the capacity of health systems and their preparedness to respond to the climate change challenge. These include:

- Strengthening health security, maximizing synergy with existing instruments such as the International Health Regulations, preparing the health workforce to deal with extreme events (e.g. by offering appropriate mental care during emergencies as well as adequate care for extended periods afterwards to the survivors), and ensuring that the logistic aspects of the health system infrastructure can withstand extreme events (e.g. by making available stand-by generators, providing capacity to ensure safe drinking water, and maintaining adequate removal/disposal of sanitary and medical waste, etc.);
- Building the capacity of the workforce: health professionals should be prepared for new challenges in protecting health from the effects of climate change;
- Providing intelligence: ensuring that information systems and communication strategies serve the needs of the health care system in a multi-sectoral context. A robust information infrastructure should be capable of:
  - providing reliable and timely information;
  - issuing warnings;
  - acting on early warnings received from other partners. Surveillance and communication strategies should be (i) transparent; (ii) building trust and making risk assessment more understandable for the public, and (iii) better supporting overall management of extreme climatic events.

Source: Menne, B. et al., 2008. Protecting health in Europe from climate change. WHO-Europe. Online at: http://www.euro.who.int/Document/E91865.pdf.

Extreme events often alter risk and vulnerability perception among policy-makers, water managers and the population, generally raising their sense of urgency for adaptation to be undertaken, at least in the short term. Extreme events can therefore accelerate the implementation of medium- and long-term adaptation strategies and should be used accordingly. Droughts, for example, can be occasions to shift regional economies away from water-intensive crops to other forms of economic activity and agriculture that are less climate-sensitive.

7.3 Dealing with uncertainty

Because of the uncertainties over the impacts of climate change on the water environment, where possible measures that can cope with a range of future climate conditions should be chosen. The following types of measures should be prioritized (in decreasing order of priority) taking into account the transboundary context as well:

- **Win-win options** – cost-effective adaptation measures that minimise climate risks or exploit potential opportunities but also have other social, environmental or economic benefits. In this context, win-win options are often associated with those measures or activities that address climate impacts but which also contribute to climate change mitigation or meet other social and environmental objectives. For example, encouraging the efficient use of water, and particularly hot water, in households is a win-win option, reducing demand on water resources and also mitigating climate change by reducing carbon emissions from water heating;

- **No-regrets options** – cost-effective adaptation measures that are worthwhile (i.e. they bring net socio-economic benefits) whatever the extent of future climate change. These types of measure include those which are justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing risks associated with projected climate changes. For example, promoting good practice in soil management to limit the risks of diffuse pollution is a no-regrets option;

- **Low-regrets (or limited-regrets) options** – adaptation measures where the associated costs are relatively low and where the benefits, although mainly met under projected future climate change, may be relatively large. For example, constructing drainage systems with a higher capacity than required by current climatic conditions often has limited additional costs, but can help to cope with increased run-off as a result of expected climate change impacts;

- **Flexible adaptation options** – measures which are designed with the capacity to be modified at a future date as climate changes. Influencing the design of a reservoir so that its capacity can be increased at a future date, if necessary, would be an example of flexible adaptation.

Another approach to deal with uncertainty is to evaluate the capacity of current strategies to adapt. This can identify future situations where maintaining a strategy becomes unsustainable in terms of affordability, social acceptability, and/or spatial or technical feasibility. Before these "points of reconsideration" are reached, alternative strategies must be developed.

A similar approach is to identify water management paths that have inherent thresholds beyond which they are technically, economically, environmentally or socially unsustainable, and then focus from the start on paths that are not so dependent on thresholds. Where river regulation is concerned, for example, in many situations structural approaches face clear thresholds (the limits of sea level rise beyond which levees can withstand storm surges, the flow volumes embankment systems are capable of protecting regions against, the sediment loads beyond which dam life spans become uneconomic, for example).

It is also important to recognize that water management strategies differ greatly in their ability to function effectively under high levels of variability and uncertainty. Some measures are more adapted to variability than others. Large-scale structural measures, for example, often require accurate information regarding flows, sediment loads, extreme event frequencies and other hydrological characteristics if they are to be designed effectively. Other approaches which emphasize more open basin strategies (local distributed storage, drainage and the protection of smaller areas) and rely on the absorptive capacity of riparian and wetland areas may be more resilient under highly variable conditions.

It is often difficult to shift strategies once they are initiated – populations protected by levee systems, for example, are often economically, socially and politically difficult to move even if the levee becomes technically inadequate for dealing with river flows. As a result, selecting water management pathways that are resilient under uncertainty is important from the start.

However, climate change will also result in "surprises" – impacts that are difficult if not impossible to project and that emerge as a consequence of complex interactions between climate and other systems at various levels ranging from the local to the global. As a result, while it is important to try to identify sources of vulnerability and to design adaptive responses in advance, the ability to respond to surprise depends on the overall resilience of the society and its inherent adaptive capacities. This depends on institutional flexibility and the presence of resilient and flexible transport, communication, education, and other systems that allow regions to shift strategies as conditions change.

7.4 Development and implementation of adaptation strategies and measures

Within the overall objectives of striving for economic efficiency, environmental sustainability, cultural compatibility and social acceptance, specific broad objectives of the adaptation strategy should be defined at the beginning of the process of developing adaptation options.

As a first step, ongoing and new policies and measures for adaptation or water management in general should be assessed vis-à-vis their capability to cope with current and future climate variability and climate change and to reduce vulnerability (see box 31).

As a second step, alternative available adaptation measures should be described. The description of measures should indicate the objective(s), timing of and responsibilities for implementation, financial needs, technical feasibility of measures, barriers to their implementation (e.g. cultural, social), the capacity to implement and sustain them, the environmental and cultural acceptability of the technology involved, etc. This should also include the associated risks, benefits and costs of each option, the key parameters affecting the decision, in particular the key uncertainties and the sensitivity of the end results to these, and the distribution of impacts of the different options on different groups in society, over time and geographically. However, such an analysis may not be able to identify with confidence one option rather than another.

Identifying and evaluating different adaptation measures implies searching for options with low social, economic and environmental consequences, taking into account the development objectives, decision-making process, stakeholder considerations and the resources available. Options may be explored through various methods ranging from systematic qualitative analysis, semi-quantitative analysis in order to compare different attributes or parameters, and full quantitative analysis of risks, costs and benefits. Examples of methods to perform such analyses are: cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis, and expert judgement. The "best" or "preferred" option may involve a combination of elements from various options. SEA is a decision support tool with a legal basis in a growing number of countries that aims to identify and evaluate options in a participatory way and executes a comparative evaluation of those options from a cross-sectoral perspective. SEA can therefore give support in selecting adaptation measures.

The costing of measures is a prerequisite for ranking them and for determining their future funding. The costs and benefits of alternative strategies should be compared. Costs should include both one-off expenditures for capital investments, as well as recurrent costs, including

Box 31: Making Water Management Measures Climate-resilient

Any new water management measures taken should be climate-resilient. Ensuring this entails appraising whether the measure is robust when faced with climate change impacts and assessing impacts relevant for climate change which will possibly be caused by the measure. The following steps should be undertaken to arrive at climate-resilient measures:

1. The first step is to assess the vulnerability of the measure regarding climate change, i.e. its sensitivity against anticipated climate change impacts such as changes in precipitation patterns and amount, increasing temperatures, etc. If the sensitivity is assessed as low, the measure can be considered climate-resilient, but its impact on climate change still needs to be assessed.
2. If the sensitivity is medium or high, the possibility of adjusting the measure to react to expected climate change impacts has to be tested, and the implications this would have on the sensitivity and the costs of the measure in question. If the sensitivity can be reduced the measure can be considered climate-proof, but its impact on climate change still needs to be assessed.
3. If the vulnerability of a measure with respect to its intended effectiveness is high, it is necessary to check whether this vulnerability affects the overall benefit of the measure. If the measure offers substantial additional benefits its application is justified and one can proceed with the impact assessment.
4. Because of often limited knowledge and a certain level of uncertainty concerning the impacts of climate change on the water bodies, the best option is to choose only measures that can cope with a range of future climate conditions and are sufficiently adaptive to these.

Some measures also exacerbate the effects of climate change, which is called "maladaptation". To avoid this for all measures that have been assessed as climate-proof it has to be clear that they neither affect the vulnerability of the river basin negatively nor are counterproductive with respect to other adaptation or mitigation objectives. So, water management measures also have to be assessed against the following aspects:

- Compatibility with other adaptation actions. Will the measure enhance or weaken the adaptive capacity of the river basin?
- Assessment of the potential contribution of the measure to future climate change. Will the measure have impacts on e.g. greenhouse gas emissions? How much energy is needed for the measure and are there alternative, more energy-efficient measures?

Source: European Commission, 2009. River basin management in a changing climate – a Guidance Document. Draft version 2 (4 September 2009) under development in the frame of EU Water Framework Directive Common Implementation Strategy.

operational costs. Apart from direct costs, there are often indirect costs (e.g. in the form of an additional burden to the administrative system of the country) and external costs (linked for example to negative impacts in another sector). Costs should – so far as possible – be expressed in monetary form. When this is not possible – as may be the case, for instance, in relation to changes in ecosystems – these factors have to be incorporated qualitatively. Methods have been developed to successfully quantify and value the use of resources for which there is no market price; such methods can be used in the formulation process.

To estimate the benefits of measures, their impacts on the environment and on society can be determined by comparing the "with" and "without" cases (see box 32 for an example). These impacts need to be described in terms of their contribution to the objectives of the strategy, again preferably in monetary terms. As is the case with costs, impacts may be system-specific (e.g. human health, agriculture, environment, biodiversity, infrastructure, etc.), and be multi- or cross-sectoral. Costs and benefits are mirror images and often benefits result in reduction of the (social) costs. The evaluation of options should include equity considerations and assessing to whom the benefits accrue.

Processes for cost benefit analysis are often as important as the results of such analyses. Transparent processes that encourage high levels of participation can build public and key stakeholder support for adaptive measures and also ensure that all costs and all benefits are adequately represented in the analysis. Cost-benefit analyses should therefore undergo substantial participation and peer review.

Appraisals of adaptation actions should always compare their benefits with their costs, appropriately discounted over time, while

Box 32: Cost-benefit Analysis of the Dutch Delta Committee

In 2007, the Dutch government installed the so-called Delta Committee to formulate a vision of the long-term protection of the Dutch coast and the low-lying hinterland against the consequences of climate change. The challenge is how to climate-proof the Netherlands in the very long term, making it safe against flooding while still remaining an attractive place to live and work, for recreation and investment. The Committee came up with recommendations for a “Delta Programme” based on assumptions of a regional sea-level rise of 0.65 to 1.3 m by 2100, and of 2 to 4 m by 2200 including the effect of land subsidence, and maximum (design) discharges of the Rhine and Meuse of around 18,000 m^3/s and 4,600 m^3/s respectively by 2100.

Most of the Dutch population lives immediately behind the coast, in the low-lying areas of the Netherlands below sea level. This region is also the centre of the nation’s economy. Nearly nine million people live here, protected by dykes and dunes along the coast, the main rivers and the lakes, while roughly 65 per cent of GNP is generated here. The major docks and airports on or near the North Sea are vital nodes in the international transport network as well as important locations for the goods and services industries. These are important reasons for the Netherlands to maintain strict standards for flood protection.

In 2008, the national wealth was about €2,750 billion, excluding ecological, landscape and cultural values. Since an estimated 65 per cent of this wealth lies in flood-prone areas, the wealth that is potentially under threat is of the order of €1,800 billion. The potential economic damage (direct and indirect) due to flooding has been estimated as approximately €190 billion, taking into account that the damage varies according to the water depth per area surrounded by dykes. The potential damage would increase to €400 – €800 billion in 2040 and €3,700 billion in 2100 in the absence of any measures, given a sea level rise of 24 to 60 cm in 2040 and 150 cm in 2100. The Committee estimated that implementation of the Delta Programme until 2050 would involve a cost of €1.2 to €1.6 billion per annum, and €0.9 to €1.5 billion per annum in the period 2050–2100.

The Committee says visions of the future development of the Netherlands generate ideas for possible projects, while cost-benefit analyses force the users to develop concrete plans, thus allowing projects to be compared and assessed according to their costs and benefits to society. But a cost-benefit analysis cannot be used as the only tool for making a decision. Good political choices depend on both visions and calculations. Given the high stakes, the Committee states that the Netherlands should devote at least 0.5 per cent of its GNP to water safety. The estimated total costs for water safety, including management and maintenance costs, add up to approximately 2.4 to 3.1 billion Euros per annum which is approximately 0.5 per cent of GNP. The Committee therefore concludes that the costs of the proposed measures are economically reasonable and viable.

Reference: http://www.deltacommissie.com/en/advies.

non-monetary values should also be taken into consideration. In particular, cost-benefit and cost-effectiveness analyses should include equity considerations, which are vital to choosing measures that are effective and just.

Discounting (a method for evaluating costs and benefits over time, used to compress a stream of future costs and benefits into a single present value amount) is an important concept because it can have a major effect on the outcome of the cost-benefit calculation. For example, a high discount rate (the rate at which society is willing to trade off present for future consumption) will favour avoiding the costs of adaptation now, whereas a low discount factor encourages immediate action. Setting the discount rate is a controversial issue which cuts into ethical and philosophical issues related to defining the social welfare function across generations. As shown in the Stern Review (see its chapter 2 and its annex 2A), it is also technically complex as it requires growth paths and allocations across time to be specified.

Setting priorities requires choosing criteria to weigh different concerns. These criteria can also act as indicators of the success or failure to realise the objectives, and can be used by a monitoring-evaluation programme for the adaptation strategies, policies and measures (see chapter 9). Table 2 provides an overview of questions to be asked.

Table 2: Criteria and indicators for appraisal of adaptation actions

CRITERION	INDICATORS/SUB-CRITERIA	QUESTIONS TO BE ASKED
Effectiveness of adaptation	Adaptation function	Does the measure provide adaptation in terms of reducing impacts, reducing exposure, enhancing resilience or enhancing opportunities?
	Robustness to uncertainty	Is the measure effective under different climate scenarios and different socio-economic scenarios?
	Flexibility	Can adjustments be made later if conditions change again or if changes are different from those expected today?
Side-effects	No regret	Does the measure contribute to more sustainable water management and bring benefits in terms of also alleviating already existing problems?
	Win-win (or win-lose)	Does the measure entail side-benefits for other social, environmental or economic objectives? For example, does it • Contribute to closing the gap between water availability and demand? • Affect the delivery of other water management objectives (e.g. river flow)? • Create synergies with mitigation (e.g. does it lead to decreased GHG emissions)?
	Spill-over effects	Does the measure affect other sectors or agents in terms of their adaptive capacity? Does the measure cause or exacerbate other environmental pressures? Does the measure contribute to mitigation?
Efficiency/costs and benefits	Low-regret	Are the benefits the measure will bring high relative to the costs? (If possible, consider also distributional effects (e.g. balance between public and private costs), as well as non-market values and adverse impacts on other policy goals)
Framework conditions for decision-making	Equity and legitimacy	Who wins and who loses from adaptation? Who decides about adaptation? Are decision-making procedures accepted by those affected and do they involve stakeholders? Are there any distributional impacts of the climate change impacts or of the adaptation measures?
	Feasibility of implementation	What barriers are there to implementation? • Technical • Social (number of stakeholders, diversity of values and interests, level of resistance) • Institutional (conflicts between regulations, degree of cooperation, necessary changes to current administrative arrangements)
	Alternatives	Are there alternatives to the envisaged adaptation measure that would e.g. be less costly or would have fewer negative side-effects?
	Priority and urgency	How severe are the climate impacts the adaptation measure would address relative to other impacts expected in the area/river basin/country? When are the climate change impacts expected to occur? At what timescales does action need to be taken?

Source: Draft guidance on River basin management in a changing climate – a Guidance document. Draft version 2 (4 September 2009) under development in the frame of the EU Water Framework Directive Common Implementation Strategy.

Uncoordinated sectoral responses can be ineffective or even counter-productive because responses in one sector can increase the vulnerability of another sector and/or reduce the effectiveness of adaptation responses taken in that sector. Hence there is a need to adopt a cross-sectoral approach when formulating and evaluating options. This is even more important for water, on which many other sectors rely.

The process of formulating options and prioritising and selecting adaptation measures should involve a wide array of stakeholders. It is important that stakeholders are involved during all steps of the process (choice of method, choice of criteria, and use of the method). To identify relevant stakeholders an analysis should be carried out. In particular, persons at risk should be involved. Use of local knowledge and expertise, garnering support and mobilizing local resources increases the effectiveness of adaptation.

There is often a gap between adaptation assessment and planning, on the one hand, and implementation on the other. This is due to a number of constraints including lack of capacity, data, information and resources. It is therefore crucial that the planning of adaptation measures closely considers all aspects that could hamper implementation.

Box 33: Flood Prevention and Preparedness in the Context of Climate Change – the Case of the Oder on the German-Polish Border

INTRODUCTION

The Oder River forms the border between Germany and Poland for about 170 km. The discharge pattern is characterized by a high flow rate during snow melt periods in low mountain ranges and by low discharges in the summer. Heavy upstream rainfall leads to floods. Long spells of rain can also cause devastating floods as the past shows, notably the summer of 1997. Today technological solutions are more feasible. Since the complexity of issues for a wider region is becoming increasingly important, cross-sectoral issues have to be taken into account and solved as a whole. Also the historical development of a region, e.g. its cultural landscape, or the ownership of land and other user rights, is important if widespread interference is needed to provide the region concerned with suitable flood protection. In particular, various land use interests and requirements, natural conditions, legal requirements and the recovery of unexploded ordnance from the Second World War have to be seriously considered in searching for a suitable concept. Considering the long-term implementation of measures, finance is a serious issue too.

INVESTIGATIONS

A comprehensive investigation of potential retention areas was made. Hydraulic calculations with different models were completed, including various scenario analyses to figure out the best solution for a deliberate purpose-oriented opening of polders retention areas in order to reduce the water level in the Oder during possible future floods. Model calculations were made for potential flood polders and potential versions of dyke relocations as well as a combination of both. The dykes on the German side along the Oder will be reconstructed step by step to cope with floods that are expected once in 200 years. The establishment of potential retention areas as well as dyke relocations is directly integrated into these dyke reconstruction measures. Seventy-five per cent of 163 km of dykes have already been reconstructed, partly with the financial support of the European Union. In addition, the hydrological forecast was improved through the development of a water-level forecast model (WVM). Operational input data of the upper reach for this model are provided at a selected stream-flow gauge on the Polish territory. Additionally, high resolution data are collected by laser scanning. The measures to be taken are communicated and discussed in the International Commission of the River Oder and the bilateral German-Polish water commission.

After disastrous floods, which are usually accompanied by extensive technical failures of hydraulic structures, the process of reconstruction is generally only feasible when based on a long-term plan and when planning and financing are considered together. Time and costs, in particular, play an important role as other issues like climate change become ever more important. Establishing whether climate change will influence the measures to be taken, and if so how, is essential.

OUTLOOK

When the long-term planning process started as long ago as 1997, climate change was hardly ever addressed as a priority for water planners. But it is now recognised as a source of pressure whose impacts have to be taken into account for further flood protection planning. This shows that planned measures will need to be adjusted.

Source: Brandenburg State Office for Environment. BMBF-Project Study on simulation of flood in the Oder River basin with a linked model system (Germany)

Box 34: Flood Risk Management in the Czech Republic: The Cases of the Floods in July 1997, August 2002 and April 2006, Measures and Lessons Learned

As the twentieth century gave way to the twenty-first the Czech Republic was affected by three catastrophic floods for which it was not properly prepared. The last disaster with fatal consequences had occurred at the end of the nineteenth century. After that, especially in the second half of the twentieth century, water management in the former Czechoslovak Republic had concentrated on the construction of dams, built to provide flood protection only as one of many purposes. Their retention capacities were effective only for smaller floods.

In 1997 a flood occurred in the Morava River basin that was one of the greatest catastrophes in the Czech Republic, with a return period of over 100 years. Fifty people died, 80,000 had to be evacuated and 11,000 lost their homes. Damage included 1,621 houses destroyed, 25,000 damaged, 51 road bridges and 15 railway bridges out of action and 1,217 km of damage to the railways. The total flooded area was 11,000 km^2 and damage amounted to €2,100 million.

In August 2002, another extensive flood affected mainly the Vltava (Moldau) River basin and the Labe (Elbe) River basin downstream from the Vltava tributary. During the flood the historical centre of Prague, was also severely affected. The damage caused to property has been estimated at €2,440 million. It was the worst flood damage ever recorded on Czech territory.

There was a third flood, in 2006, when the entire territory of the Czech Republic experienced flooding, caused by the melting of an enormous quantity of snow cover in combination with heavy rainfall. But the impact, although significant, was smaller than those of the 1997 and 2002 floods.

SOLUTIONS IMPLEMENTED

After the 1997 flood financial support was provided to those affected, and a Flood Forecasting and Warning System was developed, which started work in 1999. The Strategy for Flood Protection was approved by the Czech Government in 2000; its basic principles have been embedded in the new Water Act No. 254/2001 Coll. The legislative and organizational precautions covering flood control and rescue operations significantly reduced the number of deaths in the later floods.

Flood protection measures during the flood of 2002 included the erection of newly designed mobile flood barriers in Prague on the right bank of the Vltava (Moldau) River. Experience gained in 2002 prompted the initiation of the Programme for Assessment of Extreme Floods. This Programme will be launched in the future by the government when necessary. Improvements in flood management were developed and embedded in the Water Act. The forecasting and warning service were also improved, as well as crisis management arrangements.

One reason why the 2006 flood was not as devastating as the previous two was because of experience gained during the previous floods and the measures implemented as a result. It demonstrated the effect of the harmonization of reservoir operation on the reduction of flood flows.

LESSONS LEARNED

The three serious floods prompted an interdisciplinary analysis of the harmfulness of flood events. The causes and consequences of the disasters were studied, and effective legislative, administrative and economic ways of enforcing preventive measures in some areas of activity were sought. It was recognized that state aid must be concentrated not only on coping with flood damage, but also on developing programmes for restoring natural features of the landscape, so that money is used at the same time to improve the protection of land and buildings against future floods.

The most important issues to be resolved were:

- The principles of flood prevention should be reflected more distinctly and consistently in the everyday activities of water authorities, land planners and building authorities and in their decision-making processes;
- Legislation should be amended to increase the responsibility of municipalities and regions for preparing preventive protection measures;
- The reliability of the flood warning service should be improved. The flood warning system should include the implementation of local warning systems and better co-operation between the hydrometeorological institute and river basin companies;
- More attention is needed on ways to raise public awareness, e.g. through teaching activities, special training, training for participants in flood protection systems, and in other ways;
- The Ministry of Environment should initiate a new programme to ensure the implementation of an interdisciplinary project on assessment of extreme (catastrophic) floods. Sharing activities between several sectors of the Government promotes wider public awareness of floods as the highest risk posed by possible natural disasters in the Czech Republic.

Source: Ministry of the Environment, Czech Republic. http://www.mzp.cz/__C1257131004B200D.nsf/

The final adaptation strategy should be endorsed at the appropriate political level (e.g. council of ministers or Parliament, depending on the national situation or joint body). The agreed adaptation strategy should be published and brought to the attention of all stakeholders. The strategy should be accompanied by a clear time plan for implementation of the measures, a clear distribution of responsibilities and a financial strategy (see chapter 8). Implementation should start as soon as possible after the strategy is agreed and should be regularly evaluated (chapter 9).

Monitoring compliance and enforcement are key aspects of adaptation, both for measures specifically designed to adapt to climate change as well as for existing measures that promote sustainable water use. For instance illegal water use, particularly for agricultural purposes, is a major problem in certain parts of UNECE and needs to be addressed, considering the increased frequency of droughts. It calls first for the detection of illegal abstraction sites, and then presumably for fines or penalties as a deterrent, and finally for surveillance.

7.5 Transboundary cooperation

Transboundary cooperation has two main objectives. In the first place, it aims to prevent, control and reduce transboundary impacts when designing and implementing adaptation strategies and measures. In this way it ensures that unilateral measures do not have unintended effects in riparian countries, in particular that they do not increase their vulnerability.

Beyond that, transboundary cooperation can help to enable more efficient and effective adaptation, since some measures that support adaptation in one country can be more effective if they are taken in another country. Prevention of flooding, for instance, can be realized by creating retention areas upstream, perhaps in the upstream country. Transboundary cooperation on adaptation can widen the knowledge/information base, enlarge the set of available measures for prevention, preparedness and recovery and thereby help to find better and more cost-effective solutions. In addition, enlarging the area under planning enables measures to be located where they create the optimum effect (see box 35).

In transboundary basins, some local measures might not have any transboundary impact and therefore do not need transboundary cooperation. In the case of structural and other measures likely to cause a significant adverse transboundary impact, cooperation is required. Moreover, legislative, regulatory and economic measures can benefit from a joint approach.

At the transboundary level, common objectives and goals should be defined and major planned measures discussed. Joint bodies are the natural forum for the process of developing and implementing adaptation strategies – from agreeing to their objectives to selecting, implementing and evaluating measures for the whole basin. However, the implementation of the measures agreed upon usually lies with the countries involved (see box 33 as an example).

Table 3: Overview of possible adaptation measures

TYPE OF MEASURES	FLOOD-PRONE SITUATION	DROUGHT-PRONE SITUATION	IMPAIRED WATER QUALITY	HEALTH EFFECTS
PREVENTION/ IMPROVING RESILIENCE **Measures include…**	• Restriction of urban development in flood risk zones • Measures aiming at maintaining dam safety, afforestation and other structural measures to avoid mudflows • Construction of dykes • Changes in operation of reservoirs and lakes • Land use management • Implementation of retention areas • Improved drainage possibilities • Structural measures (temporary dams, building resilient housing, modifying transport infrastructure) • Migration of people away from high-risk areas	• Reducing need for water • Water conservation measures/ effective water use (industrial and other sectors' practices and technologies, recycling/ reusing wastewater) • Water saving (e.g. permit systems for water users, education and awareness-raising) • Land use management • Fostering water efficient technologies and practices (e.g. irrigation) • Enlarging the availability of water (e.g. increase of reservoir capacity) • Improving the landscape water balance • Introduction or strengthening of a sustainable groundwater management strategy • Joint operation of water supply and water management networks or building of new networks • Identification and evaluation of alternative strategic water resources (surface and groundwater)	• Prevention of and cleaning up of dump sites in flood risk zones • Improved waste water treatment • Regulation of wastewater discharge • Improved drinking water intake • Safety and effectiveness of waste water systems • Isolation of dump sites in flood risk zones • Temporary wastewater storage facilities • Catchment protection, (e.g. increasing protected areas)	• Strengthen capacity for long-term preparation and planning, especially to identify, address and remedy the underlying social and environmental determinants that increase vulnerability • Use existing systems and links to general and emergency response systems • Ensure effective communication services for use by health officials • Regular vector control and vaccination programmes • Public education and awareness-raising • Measures against the heat island effect through physical modification of built environment and improved housing and building standards

Table 3: Overview of possible adaptation measures -Continued-

TYPE OF MEASURES	FLOOD-PRONE SITUATION	DROUGHT-PRONE SITUATION	IMPAIRED WATER QUALITY	HEALTH EFFECTS
PREVENTION/ IMPROVING RESILIENCE **Measures include…**		• Identification and evaluation of alternative technological solutions (desalinization; reuse of wastewater) • Increase of storage capacity (for surface and ground waters) both natural and artificial • Considering additional water supply infrastructure • Economic instruments like metering, pricing • Water reallocation mechanisms to highly valued uses • Reducing leakages in distribution network • Rainwater harvesting and storage • Reducing water demand for irrigation by changing crop mix and calendar, irrigation method • Promoting indigenous practices for sustainable water use • Importing water-intensive agricultural products (virtual water)		
PREPARATION **Measures include…**	• Flood warning (incl. early warning) • Emergency planning (incl. evacuation) • Flash-flood risks, (measures taken as prevention, as the warning time is too short to react) • Flood hazard and risk mapping	• Development of drought management plan • Changing reservoir operation rules • Prioritization of water use • Restrictions for water abstraction for appointed uses • Emergency planning • Awareness-raising • Risk communication to the public • Training and exercise	• Restrictions to wastewater discharge and implementation of emergency water storage • Regular monitoring of drinking water	• Strengthen the mechanism for early warning and action • Improved disease/ vector surveillance/ monitoring • Ensuring well-equipped health stations and availability of communication and transportation facilities • Developing water safety plans
RESPONSE **Measures include…**	• Emergency medical care • Safe drinking water distribution • Safe sanitation provision • Prioritization and type of distribution (bottled water, plastic bags, etc.)			
RECOVERY **Measures include…**	• Clean-up activities • Rehabilitation options such as reconstruction of infrastructure • Governance aspects such as legislation on, inter alia, insurance, a clear policy for rehabilitation, proper institutional settings, rehabilitation plans and capacities, and information collection and dissemination. • Specially targeted projects: new infrastructures, better schools, hospitals… • All kinds of financial and economic support. • Special tax regimes for investments, companies, people • Insurance • Evaluation			

Box 35: Finnish-Russian Agreement on the Discharge Rule of Lake Saimaa and the River Vuoksi

The River Vuoksi drainage area is the largest transboundary watercourse between Finland and Russia. The main part of the drainage area and the central lake, Lake Saimaa (4,500 km²), are situated in Finland. The upper part of the drainage area and the main part of the River Vuoksi, the outlet of Lake Saimaa, are situated in the Russian Federation. The main concerns in the area are a threat of flood damage to industries and houses on the shores of Lake Saimaa and the amount and timing of hydropower production in the plants on the river, two on the Finnish and two on the Russian stretch.

In 1973 the Russian part of the Joint Finnish-Russian Commission on the Utilization of Frontier Watercourses suggested starting the regulation of Lake Saimaa in order to facilitate hydropower production. The main targets from the Finnish point of view were the floods in Lake Saimaa. Continuous regulation was however strongly opposed in Finland. Several alternatives were proposed in the Commission, and finally in 1991 the Discharge Rule was accepted. Negotiations in the Commission were constructive, and the 1964 Agreement between Finland and the USSR on Frontier Watercourses and the cooperation in the Commission established in 1965 provided a good background for planning. The hydropower companies on the Vuoksi, which are also represented in the Commission, had cooperated closely for decades.

The Discharge Rule combines natural state with regulation, as it is only used to prevent damage caused by floods and droughts. As long as the water level in Lake Saimaa is in the so called normal zone (mean water level +/- 50 cm) normal water levels and discharges are maintained. If the forecasts predict that the water level will rise above the normal zone, the discharge is increased. Similarly, low water levels are raised by reducing the discharge rate.

Implementation of discharges is discussed and agreed on in consultation between the Parties of the Commission. The Discharge Rule contains guidelines and procedures for different circumstances. The effects downstream are always considered. Such an effect may be e.g. flood damage or impacts on energy production on the Russian side. After each discharge period a report is made on its effects. If the Commission comes to the conclusion that discharges have caused damage on the Russian side, the Finnish government will provide compensation.

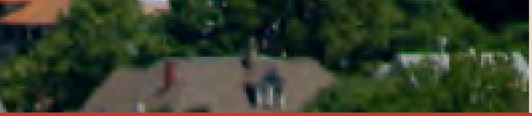
Applying the Discharge Rule has been successful and was put into practice soon after the agreement. Thanks to the Rule, flood peaks on Lake Saimaa have been lowered seven times and low water levels raised three times. Damage prevented in Finland has been about €10 million while compensation for reduced electricity production by the Russian hydropower plants has been about €1 million. Compensation is based on calculating the electricity that would have been produced if natural discharges had continued, and then calculating the difference made by the changed discharges. The monetary loss is calculated using the price of the electricity which the company would have earned. Until 2009, floods have not been very severe, and discharges could be kept at such low levels that flood damage on e.g. buildings on the Russian side was not caused.

There are still challenges in the implementation of the Rule. First of all there is not enough information on land use and possible flood damage on the shores of the river on the Russian side during severe floods. Moreover, it is not clear how damage to various types of land use could be calculated. The discharge capacity of the Russian hydropower plants is about 800 m³/s, whereas in the Finnish plants it is about 950 m³/s. This difference explains why the Russian side cannot make use of extra water discharged and thus the need for compensation.

According to calculations made by the Finnish Environment Institute, climate change will have diversified impacts on the watercourse as the time of the highest floods on Lake Saimaa will shift from July to April, and they will become more severe and more frequent. Therefore studies will be made on the possible need to modify the Discharge Rule.

Source: Finnish Environment Institute
www.ymparisto.fi

Chapter 8



Financial Matters

The private sector typically engages in adaptation in cases where it can directly benefit from its investments. Governments should complement the private sector contribution to adaptation to ensure that adaptation is funded up to the socially desirable level. This can be achieved by setting policies and putting in place an appropriate regulatory framework to help markets stimulate adaptation.

Governments should consider reallocating water to achieve greater efficiency, while taking into account equity considerations through legal provisions based on customary norms.

In a transboundary context, costs or benefits can be shared according to economic principles of efficiency although this is not always desirable.

Insurance and re-insurance also have an important role to play in adaptation to climate change.

8.1 Key concepts and relationships

The risk-based approach to climate change adaptation seeks to identify, analyse/prioritise and treat/reduce to acceptable levels both the current and future risks associated with climate variability and extreme events. When analysing risks, priority should be given to those extreme or high risks which are most likely to occur. When treating the risks, 'win-win' or 'no-regrets' treatment options should be pursued (see chapter 7).

Once the risks are well understood, it is usually necessary to develop a more detailed analysis of treatment options. A range of techniques for assessing the risk treatment options associated with climate change include cost-benefit analysis, cost-effectiveness analysis, financial analysis, general equilibrium analysis or multi-criteria decision analysis.

Such economic frameworks, adapted to the context of climate change, therefore have an important role in helping to guide the choices of policymakers on which adaptation measures to adopt. Part V of the Stern Review on the Economics of Climate Change provides a useful guide to the basic costs and benefits framework in the context of adaptation. However, such frameworks also have limitations, notably on how benefits and costs are defined or the discount rate specified.

Adaptation reduces the negative impacts of climate change and can enhance the ability of a country to capture its benefits. Its net benefit, equal to avoided damage minus its costs, is likely to increase with increasing climate impacts. The costs of adaptation measures are inversely related to the timeliness and degree of mitigation efforts.

The costs of adaptation depend on vulnerability and are therefore often concentrated in the poorest regions of the world, which are situated in places that are most exposed to the damaging impacts of climate change. However, in such contexts, adaptation measures can also be very cost-effective, especially because of projects' development-related benefits: these are often large enough to justify their implementation even in the absence of climate change (no-regrets measures). For example, new infrastructure standards can increase resistance to extreme weather events, while at the same time helping to reduce greenhouse gas emissions from buildings and creating new jobs.

8.2 A role for Governments

Market forces are unlikely to lead to an efficient adaptation outcome. This is because of the existence of three market failures that impede adaptation: uncertainty and imperfect information; missing and misaligned markets; and financial constraints. Governments have an active role to play in correcting these failures, to ensure that efficient and equitable adaptation will take place.

On uncertainty and imperfect information, more quantitative information on climate change impacts and the associated costs and benefits of adaptation at the sectoral, national and regional levels is needed. Markets, such as insurance markets, may be a source for such information. For example, it is sometimes possible to infer something about the risks associated with climate change from insurance premiums, especially where there is greater certainty about climate change impacts.

With regard to missing or misaligned markets, because of the sometimes long-term investment horizons of adaptation measures (for example, climate-proofing buildings), where costs are weighed against uncertain, future benefits, private markets may be challenged. Further, even in the case of short-term investment returns, unless private agents can reap the benefits of their investments, there will be a barrier to adaptation financing. Finally, in the case of public goods, when adaptation measures result in benefits to the wider community, the private sector is unlikely to invest in adaptation up to the socially desirable level as it will not capture the full benefits of the investment.

This means that governments should fill the gap left by autonomous adaptation, undertaken naturally by individuals, households and businesses in response to climate change. Autonomous adaptation typically occurs when the benefits accrue predominantly to those investing in adaptation. This is the case in sectors with short planning horizons and where less uncertainty about the potential impacts of climate change exists. Therefore, Governments should fund adaptation up to the socially desirable level in those areas where there will be little or no autonomous adaptation. This could include funding infrastructure investment that may be

required to manage and prevent the impacts of climate change, e.g. better water management, flood defences and agricultural extension services. It is especially important that Governments ensure that major planning and public sector investment decisions take into account climate change.

Regarding financial constraints, low income groups or poorer countries are unlikely to be able to come up with sufficient resources for adaptation actions. The impact of climate change therefore has the potential to further exacerbate existing inequalities both within and across countries. Here again, governments have an active role to play by setting up social safety nets for emergencies, for example cash or food for work and employment guarantee schemes. There is also a need for developed countries to provide financial support to poorer countries for adaptation to climate change.

Governments should promote the development, diffusion and adoption of new adaptation technologies, e.g. seawalls and irrigation or water supply technologies. In this context, there may be a role for Governments to help finance priority technology development and take-up. Beyond costing and funding infrastructure, adaptation finance is also about establishing appropriate incentives through market and fiscal instruments.

The efficient allocation of water is an important adaptation policy. To achieve this, Governments should consider reallocating water using legal provisions based on customary norms, which can include criteria such as pure economics, socio-economic considerations, employment creation, or the protection of small farmers.

In the absence of water markets, and especially in cases of water scarcity, Governments should improve water management by reallocating scarce water from low-valued to high-valued uses, provided that its equity considerations are safeguarded. This can be done through pricing mechanisms although, in practice, making certain groups such as farmers pay for water may be sometimes politically difficult. Economic models of water demand and supply can guide public policymaking in finding the most efficient allocation of water, especially in the developed economy context. They can also be useful in simply informing the discussions and debate within the political process. Theoretically, such models determine where water should be allocated when it is abundant and when it is scarce, as well as if the climate changes. Effective water use also has many other development benefits such as a more resilient distribution of water. Alternatively, Governments can assign water rights to current users and make these property rights tradable. In this case, markets are expected to reallocate water permits to higher-valued uses. However, the full recovery of capital costs does not always happen.

8.3 Funding assistance for adaptation

Governments should make full use of the multilateral funding mechanisms available to them to implement climate change adaptation. The main mechanisms for supporting adaptation are the GEF special funds for adaptation, the Adaptation Fund under the Kyoto Protocol, Official Development Assistance (ODA) and concessional lending.

GEF adopts a three-stage approach to adaptation, which encompasses a planning stage to identify vulnerabilities, policy options and capacity-building; the identification of measures for adaptation; and, finally, the facilitation of adaptation through insurance and other interventions.

Funding from the Adaptation Fund under the Kyoto Protocol depends on the quantity of certified emission reductions (CERs) issued and their price. Governments should therefore further explore the use and expansion of the carbon market as a means for financing additional adaptation needs.

Other multilateral initiatives include, inter alia, the World Bank's Pilot Programme for Climate Resilience and the Global Facility for Disaster Risk Reduction. Bilateral initiatives include Cool Earth Partnership (Japan), the International Climate Initiative (Germany), the European Commission's Global Climate Change Alliance and the UNDP-Spain Millennium Development Goal Achievement Fund.

Box 36: Market Mechanisms and Regulation in Adaptation to Climate Change

Market solutions have an important role to play in climate change adaptation. In the context of the water sector, the use of markets is widespread. For example, in England and Wales privatization in 1989 produced 10 water and sewerage companies and twelve water-only private companies. Because of the absence of competition, these regional monopolies are regulated by the Office for Water Services, known as Ofwat, which is an independent non-ministerial government department.

Ofwat uses a number of regulatory mechanisms, such as comparative efficiency, whereby monopoly companies' performance is benchmarked to assess how well they are performing. In the face of a changing climate, Ofwat aims to take a sustainable approach towards balancing the supply and demand for water, as well as to promote efficient water use; and to reduce leakage. These adaptation challenges have to be considered in the long-term context which also considers the carbon implications of water companies' activities.

Controlling demand can be effected, first and foremost, by charging for water. The generally accepted method of charging in most European countries is metering, which has a number of benefits. By directly relating water charges to household water use, metering is considered fair and can also support the introduction of a choice of tariffs on water. The English and Welsh experience has shown that the introduction of meters reduces average household demand by 10 per cent and helps companies identify water leakage. In addition, meters can encourage further carbon savings in the home through the reduction of hot water use, and for the water industry through less need to treat and pump water. In areas of serious water stress, water metering can be made compulsory for households. Beyond metering alone, a combination of metering and tariffs is seen as having the potential to save significant additional amounts of water. Innovative tariffs can offer consumers incentives to manage their own demand. For example, rising block tariffs divide water use into blocks, with each successive block attracting a higher unit price. More complex tariffs, such as those that vary as a function of the season or peak demand, often also require more intelligent metering technology. For example, smart meters allow remote reading of meters rather than manual reading, or reading peak usage, which is essential information for water companies to design their tariffs. Innovative tariffs are still only at the trialling stage and are not yet widespread. In setting tariffs, it is also important to consider the needs of vulnerable households.

In addition to tariffs, companies in England and Wales are required to find the most economically efficient way to balance supply and demand. This is based on cost-benefit analysis, which considers social, environmental and economic factors. Climate change is specifically taken into account when projecting future demand and supply within the context of regulated water companies' water resource management plans (WRMPs). These are required by the government and used for review by Ofwat in their control of prices. They form the basis for companies' business plans and set out how they will address the challenges of balancing water demand and supply over the next 25 years, specifically incorporating climate change considerations.

From 2010, Ofwat intends to introduce new water efficiency targets for water companies. These were subject to public consultation and they are focused on fulfilling the targets (outcomes) to encourage innovation. They consist of a base service target that applies to all companies and a further target to encourage additional water efficiency if it is part of a sustainable and economic way to balance supply and demand.

However, measures to control demand are unlikely to be sufficient to meet future water requirements. Therefore, on the supply side, Ofwat also imposes challenging leakage targets on companies in order to achieve sustainable leakage management which will play an important role in long-term climate change adaptation. These targets are based on the concept of the sustainable economic level of leakage (SELL), the level at which it would cost more to marginally reduce leakage than to produce the water from another source. In calculating the SELL, companies must take into account external factors, such as GHG emissions.

Other mechanisms currently under consideration by Ofwat to further encourage the application of market forces in the water and sewerage sectors include abstraction trading, the unbundling of companies' accounts to help reveal the actual cost of water, and enhanced retail competition for water. There is also significant work on competition being done in Scotland, particularly on the retail side where business customers have been free to choose their supplier since April 2008.

Source: http://www.ofwat.gov.uk/

Box 37: Financing Climate Adaptation in Ukraine and the Netherlands

In some parts of Ukraine the impacts of climate change are increasingly visible: there is an increased number of natural disasters, an increase of floods in the Carpathians, the steppes in the southern regions are turning into deserts, coastal areas become inundated (the rise in the level of the Black Sea is 1.5 mm/year) and there is an acute shortage of drinking water in the central and eastern regions.

Financing of adaptation measures is based on national and subnational plans for different areas and basins. Possible sources of funding to adapt to climate change in Ukraine are:

- State budget: Possible when the implementation of activities under the state programmes contributes to climate change mitigation;
- Loans: Loans can be sought for the construction of large infrastructure projects, like protective dams, treatment plants and irrigation systems;
- State economic incentives: For example, credit concessions and allocation of funds from GHG emission quotas sale for adaptation measures;
- Private capital: This can be attracted by means of the river basin councils and by the development of extrabudgetary targeted funds aimed at the implementation of adaptation tools that take into account all stakeholders;
- Donor assistance: To draft a national adaptation strategy and adaptation programmes, donors' support can be requested.

The Dutch have a long tradition in water management which started early in the thirteenth century. In the institutional context, three levels can be distinguished:

- At the national level, the Ministry of Transport, Public Works and Water Management is responsible for water management. Within this Ministry, the Directorate-General for Public Works and Water Management sets out the general water policy, laws and regulations and is responsible for the primary flood defences. Financing of flood protection, drainage investments and other adaptation measures at national level largely come from the national budget.
- The provinces are the second level; they are responsible for regional spatial planning and supervise the regional governmental bodies.
- The regional governmental bodies are the water boards and the municipalities. The water boards are the oldest democratic organizations of the country and they take care of regional water management. Water boards raise taxes from which the regional operational and maintenance costs, including adaptation measures, are financed. This ensures that there is no competition for national budgets, while long-term planning is guaranteed. Municipalities have their own water tasks in urban areas and deal with local spatial planning.

Sources: Zakorchevna, N., 2008. Perspectives in countries with economies in transition: the case of Ukraine. State Committee for Water management, Ukraine.

Vlaanderen, N. 2008. Financing Adaptation Measures in the Netherlands. Ministry of Transport Public Works and Water Management, the Netherlands. Presentations given during the workshop on adaptation to climate change in the water sector, Amsterdam, 1–2 July 2008.

These funds are an asset for adaptation; however, such earmarking of revenues can also lead to inefficiencies in resource allocation across government and make it more difficult to mainstream adaptation, especially if funding occurs outside the normal budgetary process. Governments should therefore aim to provide any additional funding for adaptation through the usual budgetary channels. It is also important to advocate moving from project-based to a programmatic approach, where financial adaptation mechanisms are embedded into national budgetary and policy processes.

8.4 Ecosystem services

As "natural infrastructures", biodiversity and ecosystems have an important role to play in adaptation, as pointed out in chapter 7. Nevertheless, many ecosystems are endangered and at risk of losing this function. Mechanisms for valuation of ecosystem services can prevent further degradation and support restoration of ecosystems if they are included in cost-benefit analyses for adaptation measures.

Various mechanisms, based on the "user pays" principle, can be deployed to finance biodiversity. Finance can be raised directly from certain uses of biodiversity, such as through the sustainable use or trade of biological resources, including goods such as timber and non-timber forest products and the pharmaceutical, agricultural and industrial applications of biological resources. Finance can also be raised indirectly through services such as water provision, climatic regulation, water purification, tourism and scientific research. Such financing mechanisms operate at many levels, between and within countries, from and to governments, the private sector and local communities. Payment for ecosystem services (PES) is an innovative tool for rewarding ecosystem managers for their sustainable management practices, which increase ecosystem resilience and thereby contribute to climate change adaptation.

Finance can also be raised by making sure that charges are levied on economic activities which contribute to biodiversity degradation and loss, such as pollution taxes, land reclamation bonds and waste disposal charges according to the "polluter pays" principle.

To conserve endangered species, Governments should encourage conservation to proceed on public land. For private land, Governments can explore conservation payments to encourage the conservation of habitat for endangered species. Special consideration should be given to areas with nature conservation status (e.g. Ramsar sites, Biosphere Reserves, World Heritage sites, Natura 2000 sites, Emerald sites, Important Bird Areas, etc., as well as national protected areas).

8.5 Insurance and reinsurance

Insurance can play an important role in reducing disaster risk and thus advancing adaptation to climate change (see also box 38). In the face of extreme weather events, well-functioning insurance markets transfer the risk of these events across a large pool of individuals or businesses. In the absence of insurance, these risks would be too large for private individuals and businesses to bear on their own. There is also a role for the international community to facilitate adaptation to climate change through disaster risk reduction and insurance, especially in poorer countries.

Insurance can support disaster preparedness and management if it is accompanied by requirements or incentives to take preventive measures and can therefore constitute an important element of a cost-effective adaptation to climate change risks. But traditional insurance may not be the most appropriate tool for longer-term foreseeable risks, like sea-level rise, for which a greater emphasis on and investment in basic risk reduction measures is more appropriate.

Different insurance models exist. In an insurance model where everyone contributes, the costs of extreme events to the most vulnerable are cross-subsidised by those at lower risk. This principle typically underlies government-backed insurance systems. An important drawback of such a system is that it creates moral hazard by offering no reward to those that take steps to reduce their vulnerability to climate change and adverse selection. For these reasons, the level of government subsidies should be set with great care. For example, the Organisation for Economic Cooperation and Development (OECD) recommends that "public policy should not subsidise systemic risks, as this may reduce the incentives to move away from activities that become progressively less viable under the changing climate".[17]

Market-based models distinguish between those users at greatest risk who pay more to the scheme than those who avoid risk. This leads to an efficient risk-based pricing. The drawback is that such an approach can exclude the most financially vulnerable. Governments therefore have a role in creating a financial safety net to protect the poor. Specific measures to address weaknesses in countries' financial markets may be needed to bridge existing gaps.

Insurance schemes are limited to manageable levels of risk. In the case of very high levels of risk, even insurance capacity may not be sufficient to cover costs. This opens the way for the use of alternative risk transfer mechanisms such as catastrophe bonds or weather derivatives, which transfer the risk to the capital markets. These go beyond the current securitization model, whereby the insurance company concludes a reinsurance agreement with a reinsurer.

Catastrophe bonds are high-yield debt instruments that pay private investors an above-market return when the insured event does not occur but sacrifices the interest or principal following the occurrence of the event in order to pay out policyholders' claims.

Catastrophe bonds have gained in importance since Hurricane Katrina. As they are not closely linked with the stock market or economic conditions, they offer investors a good diversification of risks and sometimes high returns. In order to satisfy the risk appetites of different investors, the risk is tranched into a number of bonds, each with different risk profiles or occurrence probabilities. One of the most challenging aspects of structuring catastrophe bond issues is the choice of loss trigger on which payment is based.

A weather derivative enables businesses that could be adversely affected by unanticipated temperature swing or unusually high snowfall to transfer this risk. Weather derivatives cover low-risk, high-probability events. In the context of the 2008 financial crisis, it is unclear to what extent such capital market instruments will continue to be relevant for transferring climate change risk.

Given the potentially vast scale of disasters and their ability to overwhelm the coping capacity of single countries, there is significant scope for recognising the benefits of regional co-operation in the area of disaster risk management, particularly risk financing.

Public-private partnerships to promote the development and use of climate-related insurance markets offer great potential for supporting adaptation. For example, the Global Index Insurance Facility (GIIF) was set up by the World Bank and the EU and is aimed at helping countries to access insurance markets for weather and disasters.

8.6 The international/ transboundary context

In the transboundary context, riparian countries should focus on generating basin-wide benefits and on sharing those benefits in a manner that is agreed as equitable and reasonable. A focus on sharing the benefits derived from the use of water, rather than the allocation of water itself, provides far greater scope for identifying mutually beneficial cooperative actions.

This solidarity in the basin might entitle upstream countries to share some portion of the downstream benefits that their practices generate, and thus share the costs of these practices. Payments for benefits (or compensation for costs) in the context of cooperative arrangements could also be considered, although this is not the norm in international treaties. Costs can be shared according to economic principles, where the party that gains most pays most, or according to other criteria. In some instances, it might be appropriate to make payments to an upstream country for management practices of the basin that bring benefits downstream (e.g. reduced flooding and sediment loads, improved water quality). Equally, if an upstream investment causes damage to a downstream country, it may be possible to consider sharing the investment benefit with the downstream country.

[17] OECD 2008.

Box 38: The Role of Insurance in the Context of Disasters

Insurance is a risk-transfer mechanism which shifts the financial burden for disaster loss to another party, thereby playing an important role in managing natural hazard risk and mitigating disaster losses. Important risk-transfer instruments in this context include index-based insurance, catastrophe pools and catastrophe bonds, which are all discussed below. In addition, social safety nets and calamity funds, which provide financial support or (medical) services to victims of disasters, can also be effective instruments for managing risk and dealing with disaster shocks.

One key issue for public policy in the insurance context is whether vulnerable groups have access to affordable and viable risk transfer mechanisms, such as insurance. Another key public policy concern is the extent to which risk transfer mechanisms provide incentives for risk reduction.

INDEX-BASED INSURANCE

In contrast to so-called indemnity-based insurance schemes, under which victims are compensated for actual loss, index-based climate-risk insurance compensates insurance holders based on a trigger value of a physical measurement of a hazard, such as rainfall. In practice, it is typically used for crop risks, whereby farmers collect insurance compensation if the measurable index reaches its trigger value, regardless of actual losses. The claim is fixed *ex ante* as a per unit function of protection purchased.

This type of insurance has the advantage of reducing moral hazard compared to indemnity-based schemes and avoiding the high costs associated with settling claims on a case-by-case basis. Under an indemnity-based scheme, insurance holders have no incentive to take corrective action to reduce their exposure to the insured risk as they will be compensated for their actual losses in any event. By contrast, in the case of index-based insurance, moral hazard is reduced because farmers will have an incentive to adopt loss-reduction measures, for example, by planting more robust crops, because they stand to gain directly from such action. If the extreme weather event occurs, they will consequently incur smaller losses as a direct result of such actions. On the other hand, if the physical trigger of the index-based scheme is insufficiently correlated with actual losses, the insurance taker will bear the “basis risk” of substantial losses that cannot be recovered.

In practice, climate-risk insurance was funded for the first time in 2006 by the World Food Programme and the World Bank Commodity Risk Management Group, to protect Ethiopian farmers from severe drought. The policy, a derivative based upon a calibrated index of rainfall data for the period March–October 2006, gathered from 26 weather stations across Ethiopia, triggered payments to farmers if the rainfall was significantly below historic averages, pointing to the likelihood of widespread crop failure. This afforded Ethiopia’s 17 million farmers protection from massive losses before they spelled destitution. Risks such as droughts can also be managed effectively under this type of contract, but they are much less suited for some disasters such as conflicts and population displacements which are harder to predict and faster to unfold.

CATASTROPHE POOLS AND RE-INSURANCE

A catastrophe pool is a public-private financial instrument which provides financial protection against catastrophic risks. The contributions by parties depend on their individual exposure to the hazards covered. Such funds can be directed toward risk transfer, in which case they are used to purchase (re)insurance. This helps to lower the cost of insurance, since the collective coverage actually acquired is greater than what could have been attained separately by each member.

A well-known example of a public-private insurance pool is the Turkish Catastrophe Insurance Pool (TCIP), which offers compulsory earthquake insurance for residential property. Turkey is an earthquake-prone country where insurance cover for earthquake exposure has historically been very low. On the supply side, insurers have been reluctant to offer extensive coverage due to the high loss potential, low capital reserves and inadequate information for evaluating risks. Demand is also low, in part because after past earthquakes the government has assumed the main financial responsibility for replacing destroyed buildings, and in part because premiums for insurance coverage were too high relative to average household income.

TCIP aims to reduce vulnerability to earthquake devastation through the establishment of a long-term reserve for post-event reconstruction. As a matter of public policy, the pricing of individual premiums allows for a degree of cross-subsidization to take place: therefore contributors in low-risk areas pay more than the actual risk value, making the insurance more affordable to poor homeowners in high-risk zones.

However, such a system may not always be financially viable, especially in situations where an insured event occurs before premiums have accumulated to cover claims, or where the event leads to more costly damage than expected. In such cases some form of risk-spreading is required, either through traditional catastrophe reinsurance – insurance for the insurer – or by means of other financial structures such as contingent credits or catastrophe bonds. In the case of TCIP, commercial reinsurance was circumvented through the participation of the World Bank which absorbed three layers of the risks through a contingent loan facility offering favourable conditions. The Bank provided a start-up facility for the fund and absorbed a fixed percentage of losses of further tranches. In the absence of contingent credits, catastrophe bonds can be issued.

References: Mills, E., 2007. *From Risk to Opportunity: 2007, Insurer Responses to Climate Change.* A Ceres Report. Available online at: http://insurance.lbl.gov/opportunities/risk-to-opportunity-2007.pdf.

Swiss Reinsurance Company, 2003. *Natural catastrophes and reinsurance.* Available online at: http://www.swissre.com/resources/15a16b80462fc16c83aed3300190b89f-Nat_Cat_en.pdf

Provention Consortium, 2006. *Global Index Insurance Facility (GIIF) Concept Note.* Commodity Risk Management Group, World Bank. Available online at: http://www.proventionconsortium.org/themes/default/pdfs/GIIF_overview_Feb06.pdf

Chapter 9

Evaluation of Adaptation Strategies

Evaluation is needed to determine the relevance, efficiency, effectiveness and impact of the adaptation strategies in light of their objectives.

Evaluation should be carried out during implementation (ongoing evaluation), at the completion of a project (final evaluation), and some years after completion (post-evaluation).

Evaluation should be based on pre-defined, quantitative or qualitative performance indicators which show the progress towards a specific objective.

If the aims of an adaptation strategy have not been reached, the root causes of both successes and failures should be analyzed through more detailed evaluation.

Learning by doing is very important since it helps practitioners to make midcourse corrections. Pilot projects should be carried out to test the chosen strategy.

Participatory evaluation can add value and enhance feasibility and acceptance.

This chapter will introduce frameworks to evaluate adaptation strategies. Evaluation is a process for determining systematically and objectively the relevance, efficiency, effectiveness and impact of the strategies in the light of their objectives. Evaluating adaptation strategies is imperative to assess their results and impacts and to provide a basis for decision-making about amendments and improvements to policies, strategies, programme management, procedures, and projects. Evaluation is the responsibility of decision makers and should guide and support governmental decision-making and policy-making, as well as international aid and investment. It should support prioritizing strategies and initiatives that reduce vulnerability.

The evaluation should be done as a joint activity of riparian countries, based on their shared objectives. It should for example consider whether benefits have accrued to all riparian countries as planned, or whether adjustments need to be made. So consultations and the establishment of a joint evaluation committee will be needed.

The checklist in annex 2 can help practitioners to assess progress in adaptation.

9.1 Objectives

As explained in the previous chapters, analyses of current and future vulnerabilities and risks as well as of existing policies are the basis for developing sound adaptation strategies. Evaluation and monitoring activities are essential for verifying the efficiency of the measures taken and facilitating adjustments.

Evaluation is carried out during implementation (ongoing evaluation), at the completion of a project (final evaluation), and some years after completion (post-evaluation). Part of the evaluation can be based on self-assessment by the staff responsible, but external evaluation is also recommended.

Evaluation should be based on indicators that focus on the implementation of a policy (process indicators) and indicators that represent progress towards a specific objective (outcome indicators). Indicators can be quantitative or qualitative and should describe the positive and negative effects of project interventions. They should be defined from the beginning, i.e. when adaptation measures and objectives are decided upon, in order to enable continuous data collection and evaluation.

Evaluating adaptation strategies includes evaluating the constituent elements of a given strategy: the policy, legal and institutional setting; financial arrangements; vulnerability assessment; and the choice and implementation of measures. It also includes monitoring progress towards achieving its objectives.

The policy and institutional framework can best be evaluated by process indicators, which demonstrate actual, on-the-ground institutional and political progress in the often time-consuming, step-by-step journey to solving complex problems. They assist in tracking the domestic and regional institutional, policy, legislative and regulatory reforms necessary to bring about change.

Evaluating vulnerability assessment includes assessing whether sufficient relevant information was collected and, in the medium to long-term, whether the actual situation corresponds to the output of the model(s) selected. It should also be established whether any other population groups or regions are vulnerable. This allows the relevance and quality of the methodology used for the vulnerability assessment to be assessed.

Monitoring progress in adaptation includes collecting information on all these elements as well as on the progress made towards achieving objectives; the outcome indicators. Six types of outcome indicators to measure the success of adaptation strategies can be distinguished:

- Coverage: the extent to which projects reach vulnerable stakeholders (e.g. individuals, households, businesses, government agencies, policymakers) and ecosystems;
- Impact: the extent to which projects reduce vulnerability and/or enhance adaptive capacity (e.g. through bringing about changes in adaptation processes: policymaking/planning, capacity-building/awareness-raising, information management);
- Sustainability: the ability of stakeholders to continue the adaptation processes beyond project lifetimes, thereby sustaining development benefits;
- Replicability: the extent to which projects generate and disseminate results and lessons of value in other, comparable contexts;
- Effectiveness: the extent to which the objective has been achieved, or the likelihood that it will be achieved;
- Efficiency: the outputs in relation to inputs, looking at costs, implementation time, and economic and financial results. In measuring efficiency, it is important to remember that long-term objectives (as dealt with in climate change adaptation) require cost-benefit analysis that takes account of long-term developments.

Evaluation methods should also include performance under climate impacts (e.g. is the overall impact of an extreme event lower than before given similar circumstances), comparison of the project area with another similar area where no intervention took place, measuring outcome against standards (e.g. benchmarking) and targets. Changes in vulnerability and adaptive capacity as well as process and outcome indicators can also be used.

Sound evaluations can be carried out with simple, careful examinations of success, relative to what was expected. The following list provides examples of questions that can contribute to this evaluation:

- If, for instance, adaptation involved investing in a protection project in response to a climate hazard, then the evaluation should determine whether losses have continued, grown or been abated;
- If the protection project simply tried to reduce sensitivity to extreme events, has it worked, and how?;
- Have episodes of intolerable exposure become more or less frequent?;
- Has the definition of "intolerable" in terms of physical effects changed?;
- Has the investment expanded the coping range, reduced exposure to intolerable outcomes that exceed the range, or both?;
- Have things stayed the same or grown worse because the adaptation was ineffective, or because unanticipated stresses have aggravated the situation?;
- Is there a causal relationship between the vulnerability reduction and the strategy/measure?.

If the aims of an adaptation strategy have not been reached, the root causes of both successes and failures should be analyzed. This can be done through various methods such as a survey among the population, expert interviews, site visits, etc.

There are several difficulties in evaluating climate change adaptation projects and strategies as the logic is contrary to most evaluation efforts: a strategy can be wrongly considered a success when nothing happens and the current situation is maintained since short-term weather effects may hide long-term changes and the evaluation usually happens before the real impacts become known. Since impacts are long-term, evaluation is mid-term at best. It is also often difficult to directly credit the project with the outcome, so baseline monitoring is necessary. Finally, sectors need to be involved in the evaluation as the results of adaptation measures implemented might have different effects in different sectors.

9.2 Learning by doing

Learning by doing enables users:

- To make midcourse corrections to the implementation of adaptation strategies, so that they meet their objectives more efficiently;
- To improve their understanding of what determines adaptive capacity, so that capacity development activities can be more successful from the start.

Pilot projects represent an important method for assessing the effectiveness of an adaptation strategy. They can focus on a specific step of the strategy, a specific city or region, or any other aspect of the strategy. In order to enable effective learning to happen, pilot projects should include clear indicators of success and sufficient resources for monitoring and evaluation.

To learn from mistakes and successes, it is important to combine these insights to:

- Compare actual experience with the initial appraisal of the situation , and with the criteria adopted;
- Construct a revised adaptation baseline that describes how the system would have performed in the absence of adaptation.

Establishing an international platform is important for exchanging lessons learnt, best practices and failures. Since little experience is available yet in developing adaptation strategies and measures, and even less at the transboundary level knowledge developed by countries and experiences in implementing measures in basins, both successful and less successful examples, can help other countries to reduce risks, including environment-related health-risks and to improve their adaptation strategies.

9.3 Participatory evaluation

Participatory processes in support of adaptation can add value, enhance feasibility and acceptance and lead to more accurate results. Engaging as many stakeholders as possible can democratize the overall process of adapting to climate change and climate variability. For example, stakeholder engagement can uncover obstacles and reasons for the failure of adaptation projects, such as scepticism on the part of stakeholders about the information provided by government. However, participatory evaluation needs to go hand-in-hand with scientific evaluation which often takes into account more long-term issues.

9.4 Social, economic, political, financial, ethical and environmental considerations

In evaluating adaptation strategies, it is necessary to (re)consider the social, economic, political, environmental and ethical implications of each adaptation measure. The impacts on all stakeholders need to be considered.

Evaluation of adaptation strategies also includes cost-benefit analysis. Adapting to climate change entails costs (at least those of implementation), but should also yield significant benefits – those of reduced impacts or enhanced opportunities. Any assessment of the economic efficiency of adaptation actions requires consideration, including at the transboundary level, of: (a) the distribution of their costs and benefits; (b) the costs and benefits of changes in those goods that cannot be expressed in market values; and (c) the timing of adaptation actions.

Box 39: Monitoring and Evaluation Indicators for Global Environment Facility International Waters Projects

GEF requires its projects to include monitoring and evaluation (M&E) provisions both as a corrective function during the project cycle, enabling timely adjustments, and as a guide to structuring future projects more effectively. Three types of M&E indicators are distinguished: process indicators, stress reduction indicators, and environmental status indicators. Process indicators characterize the completion of institutional processes on the multi-country or the national level that will result in joint action on necessary policy, legal and institutional reforms and investments that aim to reduce environmental stress on transboundary water bodies. Whereas process indicators relate to necessary reforms or programmes, stress reduction indicators represent documentation evidence that an on-the-ground action did occur. They relate to the specific measures on the ground implemented by the collaborating countries. Often a combination of stress reduction indicators in several states may be needed to produce detectable changes in transboundary waters. Environmental status indicators are measures of actual performance or success in restoring and protecting the targeted water body. They should be established jointly by countries so that they can be monitored by countries undertaking harmonized monitoring programmes and reported to the relevant parties and stakeholders. Social indicators may also be appropriate here to measure whether communities and stakeholders benefit from the changes in environmental conditions brought about by the project.

Examples of process indicators include:

- Establishment of country-specific inter-ministerial committees to engage key ministries, and of a high-level (and transboundary) steering committee as well as of a science advisory panel in the joint institutional framework for sound science advice
- Stakeholder involvement in the preparation and creation of a stakeholder involvement plan (including information dissemination, consultation, and participation)
- High-level political commitment to follow up joint action, for example by ministerial-level declarations or by adoption of a joint legal/institutional framework, for example the adoption by the governments of each state of national policy, strategy, and action programmes to reduce salinity and cut irrigation water use in the Aral Sea basin.
- Adoption of an M&E plan during project preparation that includes the establishment of process indicators, stress reduction indicators, and environmental status indicators.
- Completion of a country-endorsed adaptation strategy that establishes priorities, identifies vulnerable groups and the root causes of the vulnerabilities, and is endorsed by countries. It should contain both regional and country-specific policy, legal, and institutional reforms and priority investments that address the identified vulnerabilities.

Examples of stress reduction indicators include:

- Point source pollution reduction investment completed (amount of pollutants).
- Non-point source pollution programmes implemented (area treated with best management. practices; amount of pollution reduced).
- Amount of groundwater or wetland area placed in protected management.
- Reduced releases of pollution to groundwater recharge zones.
- Additional releases of water from dams for environmental purposes.
- Reduction of irrigation water use and increase of effective water flow to delta wetlands.
- Achievement of sustainable levels of investment in the effective management of water resources and of salinity from private and public sources.

Examples of environment status indicators include:

- Improved (measurable) chemical, physical (including flow regimes), or biological parameters.
- Changes in local community income and social conditions as a result of improvements in environmental conditions.
- Improved hydrological balance as the number of hectares of trees increases as a result of reforestation programmes.
- Increased stakeholder awareness and documented stakeholder involvement.

Source: Duda, A., 2002. Monitoring and Evaluation Indicators for GEF International Waters Projects. Monitoring and Evaluation Working Paper 10. Global Environment Facility. http://www.gefweb.org/M_E_WP__10.pdf.

Annex I: Definitions

For the purpose of this Guidance, the following definitions should be considered:

Adaptability/adaptive capacity: In the context of both social and natural systems, adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities or to cope with the consequences (IPCC, 2007a).

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007a).

Adaptation strategy: The adaptation strategy for a country, a basin or part thereof, refers to a general plan of action for addressing the impacts of climate change, including climate variability and extremes. It will include a mix of policies and measures with the overarching objective of reducing the country's vulnerability (UNDP, 2004).

Autonomous adaptation: Refers to the changes that natural and (most) human systems undergo in response to changing conditions in their immediate environment, irrespective of any broader plan or policy-based decisions (Carter et al., 1994).

Climate change: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods' (UNFCCC, 1992).

Climate model: A numerical representation of the climate system based on the physical, chemical and biological properties of its components and their interactions and feedback processes, accounting for all or some of the system's known properties (IPCC, 2007a).

Climate prediction: A climate prediction is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, e.g., at seasonal, inter-annual or long-term time scales. See also climate projection and climate (change) scenario. It is different from a climate forecast, as the latter gives precise values of determined variables (more accurate in the short-term than in the longer-term) (IPCC, 2007a).

Climate projection: The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate predictions, in that the former critically depend on the emissions/ concentration/ radiative forcing scenario used, and therefore on highly uncertain assumptions of future socio-economic and technological development (IPCC, 2007a).

Climate proofing: Identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation and decommissioning (ADB, 2005).

Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models (IPCC, 2007a).

Coping capacity: The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general, this involves managing resources, both in normal times as well as during crises or adverse conditions. The strengthening of coping capacities usually builds up resilience to withstand the effects of natural and human-induced hazards (ISDR, 2004).

Discounting: A method used to evaluate costs and benefits over time, used, for example, to compress a stream of future costs and benefits into a single present value amount. Present value calculations of costs and benefits are then used to determine cost-benefit ratios, which underlie public policy choices. The selection of a discount rate is therefore a key consideration and one which is controversial. The discount rate represents the rate at which society is willing to trade off present for future benefits. Typically, the discount rate is positive due to positive inflation, opportunity cost, uncertainty and the nature of (human) preferences (Stern 2006).

Downscaling: A method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses (IPCC, 2007b).

Emission scenario: A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (e.g. demographic and socio-economic development, technological change) and their key relationships (IPCC, 2007a).

Environmental flow: The water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated (Dyson et al., 2008).

Hydrological model: A simplified, conceptual representation of a part of the hydrological cycle, primarily used for hydrological prediction and for understanding hydrological processes. Hydrological models can be based on statistical approaches (black box systems) or based on process descriptions (known as deterministic hydrology models), in the effort to represent the physical processes observed in the real world (WMO 2009).

Impact: Any effect caused by a proposed activity on the environment, including human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures, or the interaction among these factors. It includes effects on cultural heritage or socio-economic conditions resulting from alterations to those factors (UNECE, 1991).

Local: Refers to all relevant levels of territorial unit below the level of the State (UNECE, 1997).

Mitigation: Is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and to enhance greenhouse gas sinks (IPCC, 2007b).

Moral hazard: The prospect that a party insulated from risk may behave differently from the way it would behave if it were fully exposed to the risk. In the context of insurance, if an individual has taken out insurance for a specific event occurring, he/she will have no incentive to reduce the risk of loss arising from that event through his/her own action. This is because, whether or not such action is taken, the pay-off from the event will be the same for an insured individual (Wikipedia, 2009).

Non-structural measures: Refer to policies, awareness, knowledge development, public commitment, and methods and operating practices, including participatory mechanisms and the provision of information, which can reduce risk and related impacts (ISDR, 2004).

Re-insurance: The transfer of risk from the ceding insurance company to the re-insurer, intended to indemnify the ceding company for the accumulation of losses (from a catastrophic event). Typically used to allow the ceding company to assume greater individual risks than its size would otherwise allow, and to protect it against losses (SwissRe 2003).

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (IPCC, 2007a).

Scenario: A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships (IPCC, 2007a).

Socio-economic scenarios: Scenarios concerning future conditions in terms of population, gross domestic product and other socio-economic factors relevant to understanding the implications of climate change (IPCC, 2007b).

Structural measures: Refer to any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard-resistant and protective structures and infrastructure.

Vulnerability: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007a).

Sources of the definitions used above:

ADB, 2005. Climate Proofing - A Risk-based Approach to Adaptation. Pacific Studies Series Asian Development Bank.

Carter, T.L., M.L. Parry, S. Nishioka and H. Harasawa (eds.), 1994. Technical Guidelines for Assessing Climate Change Impacts and Adaptations. Report of Working Group II of the Intergovernmental Panel on Climate Change, University College London and Centre for Global Environmental Research, London, UK and Tsukuba, Japan.

Dyson, M., Bergkamp, G. and Scanlon, J. (eds), 2008. Flow – The essentials of environmental flows, Gland, Switzerland, IUCN.

IPCC, 2007a. Climate Change 2007: Synthesis Report. Annex II – Glossary.

IPCC, 2007b. Fourth Assessment Report, Working Group II, Appendix 1- Glossary.

ISDR 2004. Terminology of disaster risk reduction, http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm, accessed June 2008.

Stern, N., 2006. The Economics of Climate Change: The Stern Review. HM Treasury. Available online at: http://www.hm-treasury.gov.uk/stern_review_report.htm.

Swiss Reinsurance Company (SwissRe) 2003. Natural catastrophes and reinsurance. Online at: http://www.swissre.com/resources/15a16b80462fc16c83aed3300190b89f-Nat_Cat_en.pdf.

UNDP, 2004. Adaptation Policy Frameworks for Climate Change. Developing Strategies, Policies and Measures. Annex A. Glossary of Terms.

UNECE 1991. Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and Protocol on Strategic Environmental Assessment. Online at: http://www.unece.org/env/eia/welcome.html

UNECE 1997. Protocol on Water and Health. Online at: http://www.unece.org/env/documents/2000/wat/mp.wat.2000.1.e.pdf.

UNFCCC 1992. United Nations Framework Convention for Climate Change, article 1.

Wikipedia 2009. Moral hazard. Online at: http://en.wikipedia.org/wiki/Moral_hazard.

WMO, 2009. Guide to Hydrological Practices, 6th edition, WMO 168, Vol. II, chapter 6.

Annex II: Checklist for Self-assessment of Progress Towards Adaptation to Climate Change

This checklist is provided as a tool for self-assessment of a country's current position. It is not meant for reporting purposes, but to help decisionmakers and policymakers look at their own situations and identify bottlenecks and, where advice can be found in the present Guidance, to address them. Please give answers that are as comprehensive as possible, especially in the "In progress" column, indicating the current status in full.

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
	1. CORE PRINCIPLES AND APPROACHES				
1.1	Does your country recognize climate change as one of the numerous pressures on water resources? Are these different pressures considered in modelling of future water availability?	Yes	To some extent	No	Chapter 1
1.2	Is a disaster risk reduction strategy in place?	Yes	In the process of development	No	Chapter 1
1.3	In the process of adaptation planning, are possible conflicts between different water-related sectors and between adaptation and mitigation strategies considered and as much as possible avoided?	Yes	To some extent	No	Chapter 1
	2. INTERNATIONAL COMMITMENTS				
2.1	United Nations Framework Convention on Climate Change	Yes, it was ratified	It is signed, but not ratified, yet	No	2.1
2.2	Kyoto Protocol to the UN Framework Convention on Climate Change	Yes, it was ratified	It is signed, but not ratified, yet	No	2.1
2.3	UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention)	Yes, it was ratified	It is signed, but not ratified, yet	No	2.3.1
2.4	Protocol on Water and Health to the Water Convention.	Yes, it was ratified	It is signed, but not ratified, yet	No	2.3.2
2.5	UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention)	Yes, it was ratified	It is signed, but not ratified, yet	No	2.3.3

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
2.6	UNECE Convention on Access to Information, Public Participation in Decision-making, and Access to Justice in Environmental Matters (Aarhus Convention)	Yes, it was ratified	It is signed, but not ratified, yet	No	2.3.4
2.7	Other agreements in place at the regional, basin or bilateral level with relevance to water resource management, pollution control or disaster coordination. Please specify and give details.	Yes, with all major neighbouring countries	Yes with some neighbouring countries	No	2.3.1
	3. POLICY, LEGISLATION AND INSTITUTIONAL FRAMEWORKS				
3.1	Is the implementation of the principles of integrated/basin water resources management (IWRM) required by the legislation of your country? Please give details regarding which principles have been reflected in legislation, and comment on extent of application.	Yes	Under Consideration	No	Chapter 1
3.2	Are river basin/integrated management plans in place?	Yes, they are in place	Required by legislation, but currently under development	No	Chapter 1,2,3
3.3	Please only answer this question if you have answered Yes or In progress in the above question 3.2 Are climate change impacts, vulnerability assessments of water resources, water balance changes, and other climate change-related issues reflected in your river basin/integrated management plans?	Yes, fully reflected	Partially reflected	No	3.3
3.4	Please only answer this question if you have answered Yes or In progress in the above question 3.2 Is there a requirement that such management plans be reviewed and updated regularly? Please specify period.	Yes	Yes, but changing water allocation priorities is very difficult	No	3.3
3.5	Does the water allocation regime permit review of existing rights, and variation / suspension of such rights when availability is limited?	Yes	Yes, but it may be very expensive	No	3.1
3.6	Has all existing legislation been assessed to see whether it is "climate-proof"?	Yes, fully	Yes, partly	No	3.3
3.7	Is there a requirement for any new law to take into account climate change impacts?	Yes, fully	Yes, partly	No	3.3
3.8	Is there a programme/ strategy for awareness-raising and education related to climate change?	Yes	Some initiatives	No	3.5

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
3.9	Has your country established river basin management institutions/bodies?	Yes	Currently being established	No	Chapter 1
3.10	Does your country apply the ecosystem approach to water ecosystems?	Yes	Currently being established	No	Chapter 1
3.11	Does your country have formally established transboundary water cooperation in accordance with the Water Convention (e.g. existing agreements, working joint bodies, etc)?	Yes	Cooperation agreements are available but not implemented	No	2.3.1
3.12	Are the obligations set out in the Water Convention fully reflected in national legislation?	Yes	Under development	No	2.3.1
3.13	Is a right of broad civil society access to redress and remedy incorporated into the national law? Please comment on the degree to which this is effective.	Yes	Under development	No	2.3.4/3.2
3.14	Are enforceable and adequate rights and obligations related to public access to information (including IWRM-related information) in place? Please comment on the extent to which public authorities make such information available when requested.	Yes	Under development	No	2.3.4/3.2
3.15	Are laws in place to establish and maintain the rights of stakeholders, including civil society organizations, and disadvantaged or underrepresented groups, to participate in decision-making? Please comment on how far this right is established and maintained.	Yes	In process of development	No	2.3.4/3.2
3.16	Are the criteria used for water resource allocation / pollution control transparent and do they allow allocators the flexibility to take account of changing resource availability?	Yes	In process of development	No	3.3
	4. INFORMATION AND MONITORING NEEDS FOR ADAPTATION STRATEGIES DESIGN AND IMPLEMENTATION				
4.1	Does your country have official database on water resources, water users, and water systems?	Yes	Under development	No	4.3/4.5
4.3	Does you country carry out research and monitoring and/or assessment of desertification processes and of droughts and floods?	Yes	Partially - research, monitoring and assessments are neither regular nor continuous	No	4.3/4.5
4.4	Does your organization /authority have digital (GIS) maps of your country's landscape, on climate change and on water resources?	Yes	Partially / Under development	No	Chapter 4

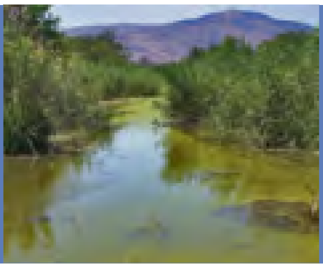
	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
4.5	Are areas where potable water is abstracted protected, and are water-related, protected zones and coastal areas and areas of climate emergency (drought, floods) included in these maps?	Yes	Partially	No	4.3
4.6	Do available data allow the development of an adaptation strategy?	Yes	Partially	No	4.3
4.7	Does your country have a joint interstate information system on transboundary basin together with riparian countries?	Yes	Partially / Under development	No	4.4
4.8	Does your country exchange information/ data with other riparian countries located in the same transboundary river basin(s)?	Yes	Partially / Under development	No	4.4
4.9	Has your country developed effective systems of water resources change (in quality and quantity) forecasting at local/national levels?	Yes	Under elaboration	No	4.4
4.10	Is there a joint monitoring system including all riparian countries?	Yes	Under elaboration	No	4.4
4.11	Is there monitoring for both surface and groundwaters?	Yes	Under elaboration	No	4.4-4.5
	5. SCENARIOS AND MODELS FOR IMPACT ASSESSMENT AND WATER RESOURCES MANAGEMENT				
5.1	Has your country elaborated national (regional) climate scenario models?	Yes	Partially / Under elaboration	No	Chapter 5
5.2	Are they harmonized/ developed jointly with neighbouring countries?	Yes	Partially / Under elaboration	No	5.4
5.3	Has your country elaborated hydrological models for assessment of climate change impact on water resources (in droughts, floods)?	Yes	Partially / Under elaboration	No	5.2-5.3
5.4	Has your country elaborated scenarios of socio-economic development on short/middle/long terms?	Yes	Partially / Under elaboration	No	5.1
5.5	Have the scenarios and models been agreed upon by all riparian countries?	Yes	Under elaboration	No	5.4
	6. VULNERABILITY ASSESSMENT FOR WATER MANAGEMENT				
6.1	Is the number of endangered aquatic species of flora and fauna increasing or decreasing (period should be reflected)?	Decreasing	No changes	Increasing	6.1

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
6.2	Is a shortage of planned water resources observed in the middle of year (period should be reflected)?	No	Yes, periodically (no more than once per five years)	Yes, constantly	6.2
6.3	Has a vulnerability assessment of aquatic ecosystems in relation to climate change been done in your country?	Yes	Partially	No	6.2
6.4	Does your country measure glaciation of the mountain areas?	Yes	Partially	No	6.2
6.5	Please only answer this question, if you have answered Yes or In progress in the above question 6.4 What is the status of glaciation cover of the mountain areas?	No changes		Decreasing	6.2
6.6	Are trends of water-related diseases increasing or decreasing in your country (period should be reflected)?	No	Decreasing	Increasing	6.1
	7. ADAPTATION STRATEGIES AND MEASURES				
7.1	Has your country developed an adaptation strategy including measures for the different stages of the adaptation chain?	Yes	Under development	No	chapter 7
7.2	Are measures chosen in a transparent, participatory process using methods such as cost benefit analysis, cost effectiveness analysis, multi-criteria analysis, and expert judgement?	Yes	Partly	No	7.4
7.3	Has there been an agreement on a transboundary adaptation strategy with all riparian countries or, at least, a consultation on national measures?	Yes	Under development	No	7.5
7.4	Does the adaptation strategy include a mix of structural and non-structural, legal or "command and control" and economic instruments, and education and awareness-raising measures?	Yes	To some extent, but not fully	No	7.1
7.5	Does the strategy include measures addressing the short, medium and long term?	Yes	Partly	No	7.2
7.6	Are the services of natural ecosystems such as wetlands recognized and used in adaptation?	Yes	To some extent, but not fully	No	7.1
7.7	Are win-win, low-regret and no-regret measures chosen as a priority?	Yes	To some extent, but not fully	No	7.3

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
7.8	Are the measures effective under different climate scenarios and different socio-economic scenarios? Can adjustments be made later if conditions change again or if changes are different from those expected today?	Yes	To some extent, but not fully	No	7.3
7.9	Are emergency management plans, for example drought management plans (if needed), in place?	Yes	To some extent, but not fully	No	7.1
7.10	Is participation of relevant stakeholders in the process of development of measures ensured?	Yes	Partly	No	7.4
	8. FINANCIAL MATTERS				
8.1	Has your government ensured that quantitative information on climate change impacts and the associated costs and benefits of adaptation at the sectoral, sub-regional and national levels is being collected?	Yes	Under development	No	8.2.
8.2	Has the government participated, or planned to participate, in the financing or co-financing of adaptation measures with long-term investment horizons, such as climate-proofing buildings or other infrastructure investments?	Yes	Under development	No	8.2.
8.3	In this context, has the government ensured that major planning and public sector investment decisions take into account climate change?	Yes	Under development	No	8.2
8.4	Has the government set up social safety nets for emergencies, aimed at supporting vulnerable income groups, for example, cash or food for work programmes or employment guarantee schemes?	Yes	Under development	No	8.2.
8.5	Has the government taken steps to improve its water management system, especially the efficiency of its water allocation system? On which criteria has it based its allocation system (economic efficiency, customary norms, etc.)?	Yes	Under development	No	8.2 and Box 36
8.6	Has the government considered charging for water?	Yes	Under development	No	8.2. and Box 36
8.7	Does the government promote the development, diffusion and adoption of new adaptation technologies, for example, irrigation or water supply technologies, complex water metering, etc.?	Yes	Under development	No	8.2.

	QUESTIONS	Self-assessment Yes	Self-assessment In progress	Self-assessment No	See Guidance section:
8.8	Has the government embedded financial adaptation mechanisms into national budgetary and policy processes?	Yes	Under development	No	8.2.
8.9	Does the state budget of your country have an environmental fund which can be used to finance measures towards adaptation of water resources to climate change?	Yes	Under development	No	8.3
8.10	Has the government developed mechanisms to finance preservation of biodiversity based on the "user pays" principle?	Yes	Under development	No	8.4.
8.11	Has the government made full use of financial risk-diversification mechanisms to reduce disaster risk, e.g. mandatory insurance, index-linked insurance, catastrophe insurance pools, bonds or weather derivatives?	Yes	Under development	No	8.5.
8.12	Is this context, has it considered and rectified barriers to entry into the insurance market, including household income constraints?	Yes	Under development	No	8.5.
8.13	Has the government considered helping to generate basin-wide benefits and sharing these in a reasonable and equitable manner with other countries or sub-regions?	Yes	Under development	No	8.6.
	9. EVALUATION				
9.1	Is the effectiveness of adaptation measures/strategies of water resources assessed in your country? Have indicators been defined and are data available for this purpose?	Yes	Partially	No	9.1
9.2	Please only answer this question, if you have answered Yes or In progress in the above question 9.1 Does the assessment of the adaptation strategy include an assessment of economic and social aspects, including the incidence of water-related disease?	Yes	Partially	No	9.1
9.3	Please only answer this question, if you have answered Yes or In progress in the above question 9.1 Are positive changes of water availability and water quality observed?	Yes	Partially	No	9.2

References



Introduction

Bates, B.C. et al. (eds.), 2008. *Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change*. Geneva, IPCC secretariat.

Christensen, J.H. et al., 2007: Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Solomon, S. et al., (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

EM-DAT: The Office of Foreign Disaster Assistance/ Centre for Research on the Epidemiology of Disasters (OFDA/CRED) International Disaster Database, Université Catholique de Louvain, Brussels, Belgium. Available online at: www.emdat.be.

IPCC, 2007. Climate Change 2007. *Impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Available online at: http://www.ipcc.ch/index.html.

Ludwig, F. et al., 2009. *Climate change adaptation in the water sector*. London, Earthscan.

UNECE, 2007. *Our waters: joining hands across borders*. *First Assessment of Transboundary Rivers, Lakes and Groundwaters*. Geneva, Economic Commission for Europe/Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Available online at: www.unece.org/env/water/publications/assessment/assessmentweb_full.pdf

WHO, 2009. *Climate change and human health.* Available online at: http://www.who.int/globalchange/climate/en/

WHO/UNECE, 2009. *Draft Guidance on Water Supply and Sanitation in Extreme Weather Events*, developed under the Protocol on Water and Health.

Chapter 1

Bates, B.C. et al. (eds.), 2008. *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change. Geneva, IPCC secretariat.

Burton, I., S. Huq and B. Lim, 2004. *Adaptation Policy Framework*. New York, UNDP.

Falkenmark, M., 2005. *Towards hydrosolidarity: ample opportunities for human ingenuity: Fifteen-year message from the Stockholm Water Symposia*. Available online at: http://www.worldwaterweek.org/documents/Resources/Reports/Report_Towards_hydrosolidarity_2005.pdf.

GWP-TAC (Global Water Partnership – Technical Advisory Committee), 2000. *Integrated Water Resources Management.* TAC Background Paper No. 4. Stockholm, GWP.

Kundzewicz, Z.W. et al., 2007. *Freshwater resources and their management*. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the IPPC Fourth Assessment Report, M.L. Parry et al. (eds.). Cambridge, United Kingdom, Cambridge University Press: 173–210.

OECD DAC network on environment and development co-cooperation 2008. *Advisory note on strategic environmental assessment and climate change.* Available online at: http://www.oecd.org/dataoecd/0/43/42025733.pdf.

Pahl-Wostl, C., J. Sendzimir and P. Jeffrey, 2009. Resources management in transition. *Ecology and Society* 14(1): 46. Available online at: http://www.ecologyandsociety.org/vol14/iss1/art46/.

Stockholm International Water Institute, 1999. *Towards upstream/downstream hydrosolidarity; A SIWI/IWRA seminar*, Stockholm, August 14, 1999. available online at: http://www.siwi.org/documents/Resources/Reports/Report5_Towards_Upstream_Downstream_Hydrosolidarity_1999.pdf

Swart, R. and F. Raes, 2007. Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? *Climate Policy*, 7 (4): 288– 303.

UNECE, 2009. *Towards climate-neutral cities: a regional perspective.* Available online at: http://www.unece.org/hlm/documents/2009/ece.hbp.2009.2.e.pdf.

Zimmermann, J.B., J.R. Mihelcic and J. Smith, 2008. Global stressors on water quality and quantity. *Environmental Science and Technology* 42 (12): 4247-4254.

Chapter 2

Co-operative programme on water and climate and Netherlands Commission for environmental assessment, 2009. *IWRM and SEA joining forces for climate proofing*. Available online at: http://www.waterandclimate.org/UserFiles/File/PersPap%2016.%20IWRM%20and%20SEA.pdf.

EC, 2007. Communication from the Commission to the European Parliament and the Council addressing the challenge of water scarcity and droughts in the European Union. COM (2007) 414 final.

EC, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for Community action in the field of water policy.

EC, 2001. Directive 2001/42/EC of the European Parliament and of the Council on the Assessment of the impact of certain plans and programmes on the environment.

EC, 2006. Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.

EC, 2007. Communication from the Commission to the European Parliament and the Council addressing the challenge of water scarcity and droughts in the European Union. COM (2007) 414 final.

EC 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

EC, 2007. Green Paper from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the regions - Adapting to climate change in Europe – options for EU action COM (2007) 354.

EC, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy.

EC, 2009. White Paper Adapting to climate change: Towards a European framework for action. COM(2009) 147 final. Online at: http://ec.europa.eu/governance/impact/docs/ia_2009/com_2009_0147_en.pdf.

GOC, 2008. 4th Global Conference on Oceans, Coasts, and Islands. Available online at: http://www.globaloceans.org/globalconferences/2008/index.html.

OECD, 2008. OECD advisory note on strategic environmental assessment and climate change. Available online at: http://www.oecd.org/dataoecd/0/43/42025733.pdf.

Ramsar Convention on Wetlands. Available online at: www.ramsar.org.

UNECE, 1992. *Convention on the Protection and Use of Transboundary Watercourses and International Lakes.* Available online at: http://www.unece.org/env/water/pdf/watercon.pdf

UNECE, 1997. *Protocol on Water and Health*. Available online at: http://www.unece.org/env/documents/2000/wat/mp.wat.2000.1.e.pdf

UNECE, 2009. Draft guidelines on the setting of targets, evaluation of progress and reporting. Available online at: http://www.unece.org/env/water/meetings/documents_WGWH.htm.

UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention). Available online at: http://www.unece.org/env/pp/welcome.html

UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and Protocol on Strategic Environmental Assessment. Available online at: http://www.unece.org/env/eia/welcome.html

UNFCCC, 1992. United Nations Framework Convention on Climate Change. Available online at: http://unfccc.int/2860.php.

UNFCCC, 2005, Nairobi Work Programme. Available online at: http://unfccc.int/adaptation/sbsta_agenda_item_adaptation/items/3633.php

WHO, 2005. Revision of the International Health Regulations. WHA58.3 Available online at: http://www.who.int/csr/ihr/WHA58-en.pdf.

Chapter 3

Drieschova, A., M. Giordano and I. Fischhendler, 2008. Governance Mechanisms to Address Flow Variability in Water Treaties. *Global Environmental Change,* 18 (2): 285–295.

Ebi, K.L., et al., 2005. Scoping and designing an adaptation project. In: Lim B.et al. (eds.) *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge, United Kingdom, UNDP/Cambridge University Press.

Fischhendler, I., 2004. Legal and institutional adaptation to climate uncertainty: a study of international rivers. *Water Policy 6:* 281–302.

Fischhendler, I., D. Eaton and E. Feitelson, 2004. The Short- and Long-Term Ramifications of Linkages Involving Natural Resources: The U.S.-Mexico Transboundary Water Case. *Environment and Planning C*, 22 (5): 633–650.

Gooch, G.D. and D.Huitema, 2008. Participation in water management: Theory and practice. Chapter 3 in Timmerman, J.G., C. Pahl-Wostl, and J. Möltgen, (eds.) 2008. *The adaptiveness of IWRM: Analysing European research*. London, IWA publishing.

Kwadijk, J., F. Klijn and M. Van Drunen, 2007. *Towards a climate-proof Netherlands,* Summary routeplanner, KvR final report 007/2007.

Perez, R.T. et al., 2005. Continuing the adaptation process. In: Lim B. et al. (eds.) *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge, United Kingdom, UNDP/Cambridge University Press.

Ridder, D., E. Mostert, and H.A. Wolters, 2005. *Learning together to manage together – Improving participation in water management.* Osnabrück, Germany, University of Osnabrück. Available online at: http://www.harmonicop.info/HarmoniCOPHandbook.pdf.

Rieu-Clarke, A., A. Allan, and B-O. Magsig, 2008. *Assessing governance in the context of IWRM*. STRIVER Policy Brief No. 8. Available online at: http://www.striver.no/diss_res/files/STRIVER_PB8.pdf.

Turton, A. R. et al. (eds.), 2007. *Governance as a Trialogue: Government-Society-Science in Transition*. Berlin, Springer-Verlag.

UNECE, 2005. UNECE Strategy for Education for Sustainable Development (CEP/AC.13/2005/3/Rev.1). Available online at: http://www.unece.org/env/documents/2005/cep/ac.13/cep.ac.13.2005.3.rev.1.e.pdf.

Chapter 4

Adger, W.N. et al., 2007. Assessment of adaptation practices, options, constraints and capacity. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry et al. (eds.), Cambridge, United Kingdom, Cambridge University Press, pp. 717–743. Available online at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter17.pdf..

Burton, J.F. et al. (eds), 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies.* Available online at: http://www.decisioncraft.com/energy/papers/hbccia/.

Leary et al., 2007. *A Stitch in Time: Lessons for Climate Change Adaptation from the AIACC Project.* AIACC Working Paper No. 48. Available online at: http://www.aiaccproject.org/working_papers/Working%20Papers/AIACC_WP48_Leary_etal.pdf.

ISDR, 2006. EWC III – Third International Conference on Early Warning: *Developing early warning systems – A checklist.* Available online at: http://www.unisdr.org/ppew/info-resources/ewc3/checklist/English.pdf.

ISDR *Words Into Action: A Guide for Implementing the Hyogo Framework.* Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. Available online at: http://www.unisdr.org/eng/hfa/docs/Words-into-action/Words-Into-Action.pdf.

Ogallo, L. et al., 2008. Adapting to climate variability and change: the Climate Outlook Forum process. In *WMO Bulletin* 57 (2): 93-103.

Ogallo, L., and C. Oludhe, 2009. Climate information in decision-making in the Greater Horn of Africa: lessons and experiences. In: *WMO Bulletin* 58 (3): 184-188. Available online at: http://www.wmo.int/pages/publications/bulletin_en/documents/58_3_ogallo_en.pdf)

UNECE Task Force on Monitoring and Assessment, 2000. *Guidelines on Monitoring and Assessment of Transboundary Rivers,* English version. Available online at: http://www.unece.org/env/water/publications/documents/guidelinestransrivers2000.pdf.

UNECE Working Group on Monitoring and Assessment., 2001. *Guidelines on Monitoring and Assessment of Transboundary and International Lakes.* Available online at: http://www.unece.org/env/water/publications/pub74.htm.

UNECE, 2006. Strategies for monitoring and assessment of transboundary rivers, lakes and groundwaters. Available online at: http://www.unece.org/env/water/publications/documents/StrategiesM&A.pdf.

WMO, 1994. *Guide to Hydrological Practices,* WMO no. 168. Available online at: ftp://ftp.wmo.int/Documents/MediaPublic/Publications/Guide_to_Hydrological_Practices/

WMO, 1999. Exchange of hydrological data and products. Resolution 25 adopted by WMO Congress General XIII.

WHO/UNECE, 2009. Draft Guidance on Water Supply and Sanitation in Extreme Weather Events, developed under the Protocol on Water and Health.

UNECE Working Group on Monitoring and Assessment. Transboundary Groundwater Karst Aquifer AGGTELEK–SLOVENSKÝ KRAS. Joint Report nos. 2 and 3, Final Report: Identification and Review of Water Management Issues – Recommendations for Improvement of Monitoring and Assessment Activities.

Chapter 5

Chub,V.E., N.A. Agaltseva, and S.V. Myagkov, 2002. *Climate change impact on river run-off for the Central Asian rivers*. Proceedings of the International Conference on Hydrology and Watershed Management with the Focal Theme on Water Quality and Conservation, vol. 2, 252–257, Hyderabad, India.

Dessai, S., et al., 2009. Do We Need Better Predictions to Adapt to a Changing Climate? *Eos* 90 (13):111–112.

Dibike, Y.B., and P. Coulibaly, 2004. *Downscaling global climate model outputs to study the hydrologic impact of climate change part I: calibration and validation of downscaling models"*, 6th International Conference on Hydroinformatics. Liong, Phoon and Babovic (eds).World Scientific Publishing Company.

Giorgi, F. et al., 2001. *Regional Climate Information- Evaluation and Projections. Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. T., Houghton (ed.). Cambridge, England, Cambridge University Press, pp.583–638.

Hanssen-Bauer, I. et al., 2003. Temperature and precipitation scenarios for Norway: comparison of results from dynamical and empirical downscaling. *Climate Research* 25: 15–27.

Harpham, C. and R. L. Wilby, 2005. Multi-site downscaling of heavy daily precipitation occurrence and amounts. *Journal of Hydrology* 312: 235–255.

Hay, L. E. and M. P. Clark, 2003. Use of statistically and dynamically downscaled atmospheric model output for hydrologic simulations in three mountainous basins in the western United States. *Journal of Hydrology* 282: 56–75.

Hellström, C. et al., 2001. Comparison of climate change scenarios for Sweden based on statistical and dynamical downscaling of monthly precipitation. *Climate Research* 19: 45–55.

Kidson, J. W. and C. S. Thompson, 1998. Comparison of statistical and model-based downscaling techniques for estimating local climate variations. *Journal of Climate* 11: 735–753.

Murphy, J., 1999. An evaluation of statistical and dynamical techniques for downscaling local climate. *Journal of Climate* 12: 2256–2284.

Murphy, J., 2000. Predictions of climate change over Europe using statistical and dynamical downscaling techniques. *International Journal of Climatology* 20: 489–501.

Scibek, J. et al., 2007. Groundwater-Surface Water Interaction Under Scenarios of Climate Change Using a High-Resolution Transient Groundwater Model. *Journal of Hydrology*, 333: 165-181.

Wilby, R. L. and Dettinger, M. D., 2000. Streamflow changes in the Sierra Nevada, California, simulated using a statistically downscaled General Circulation Model scenario of climate change. In *Linking Climate Change to Land Surface Change*, S. J. McLaren and D. R. Kniveton (eds.). Dordrecht, the Netherlands, Kluwer Academic Publishers: 99-121.

Wilby, R. L., C. W. Dawson and E. M. Barrow, 2002. SDSM — a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling & Software* 17 (2): 145-157.

Wilby, R. L., L. E. Hay, and G. H. Leavesley, 1999. A comparison of downscaled and raw GCM output: implications for climate change scenarios in the San Juan River basin, Colorado. *Journal of Hydrology* 225: 67–91.

Wilby, R. L. et al., 2000. Hydrological response to dynamically and statistically downscaled climate model output. *Geophysical Research Letters* 27: 1199–1202.

Wilby, R. L. et al., 2006. Integrated modelling of climate change impacts on water resources and quality in a lowland catchment: River Kennet, United Kingdom. *Journal of Hydrology* 330 (1-2): 204-220.

Wilby, R. L., and T.M.L. Wigley, 1997. Downscaling general circulation model output: a review of methods and limitations. *Progress in Physical Geography* 21 (4): 530-548.

Wilks, D. S., 1999. Multisite downscaling of daily precipitation with a stochastic weather generator, *Climate Research* 11: 125–136.

Yarnal, B.et al., 2001. Review. Developments and prospects in synoptic climatology. *International Journal of Climatology* 21: 1923–1950.

Chapter 6

Downing, T.E., and A. Patwardhan, 2005. Assessing vulnerability for climate adaptation. In B. Lim et al. (eds.), *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge, United Kingdom, UNDP/Cambridge University Press.

Downing, T.E. et al., 2006. *Integrating Social Vulnerability into water management*. SEI Working Paper and NeWater Working Paper No. 4. Oxford, Stockholm Environment Institute.

Lemmen, D.S., and F.J. Warren (eds.), 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*, Government of Canada, Ottawa.

Preston, B.L. et al., 2008. *Mapping climate change vulnerability in the Sydney Coastal Councils Group*. Prepared for the Sydney Coastal Councils Group and the Australian Government Department of Climate Change.

Sauri, D., 2008. Vulnerability and exposure to shocks and stresses in river basins: a review of EU research and some avenues for the future. In J.G. Timmerman, C. Pahl-Wostl and J. Möltgen (eds.), *The adaptiveness of IWRM: Analysing European IWRM research*,. London, IWA Publishing.

Sullivan, C.A., J.R. Meigh and M.C. Acreman, 2002. *Scoping Study on the Identification of Hot Spots – Areas of high vulnerability to climatic variability and change identified using a Climate Vulnerability Index*. Report to Dialogue on Water and Climate. Wallingford, United Kingdom, CEH.

Sullivan, C.A., and J.R. Meigh, 2005. *Targeting attention on local vulnerabilities using an integrated indicator approach: the example of the Climate Vulnerability Index. Water Science and Technology*, Special issue on climate change 51 (5): 69–78.

Sullivan, C.A., and C. Huntingford, 2009. *Water Resources, Climate Change and Human Vulnerability.* Paper presented to the 18th World IMACS/ MODSIM Congress, Cairns, Australia 13–17 July 2009.

Chapter 7

Adger, W.N. et al., 2007. *Assessment of adaptation practices, options, constraints and capacity.* In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry et al. (eds.), Cambridge University Press, Cambridge, UK, 717-743.

Bates, B.C. et al. (eds.), 2008. *Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change.* Geneva, IPCC secretariat.

European Commission, 2009. *River basin management in a changing climate – a Guidance Document*. Draft version 2 (4 September 2009) under development in the framework of the EU Water Framework Directive Common Implementation Strategy.

IPCC, 2007. *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M.L. Parry et al. (eds.). Cambridge, United Kingdom, Cambridge University Press.

KOHS Commission for Flood Protection of the Swiss Water Resources Society, 2007. An impact of climate change on flood protection in Switzerland, *Wasser, Energie, Luft* 1/2007, 55–57.

Lim, B., and E. Spanger-Siegfried (eds.), 2004. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures.* UNDP.

Ludwig, F. et al., 2009. *Climate change adaptation in the water sector*, London, Earthscan.

- van Beek, E.: managing Water under Current Climate Variability
- Aerts, J. and P. Droggers: Adaptaing to climate change in the water sector.
- Veraart, J. and M. Bakker: Climate-proofing.

Menne, B. et al., 2008. Protecting health in Europe from climate change. WHO-Europe. Available online at: http://www.euro.who.int/Document/E91865.pdf.

UNFCCC, 2006. Technologies for adaptation to climate change, Bonn, Germany.

Willows, R., and R. Connell (eds.), 2003. *Climate adaptation: Risk, uncertainty and decision-making.* UKCIP Technical Report.

Yohe, G.W. et al., 2007. *Perspectives on climate change and sustainability*. In: IPCC, 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry et al. (eds.). Cambridge, United Kingdom, Cambridge University Press: 811-841.

Other databases for adaptation measures and concepts are:

- UNFCCC database of submissions on adaptation planning and practices under the Nairobi work programme: The database provides a query mask to select measures according to country, geographical scale, sector and type of measure. http://maindb.unfccc.int/public/adaptation_planning/
- AMICA-CLIMATE is a European Interreg IIIC initiative that has tried to make the adaptation process more transparent. http://www.amica-climate.net/online_tool.html
- UKCIP adaptation action case studies. A national approach that is a good example of hands-on guidance for becoming active. http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=286&Itemid=423
- CIRCA website. "A catalogue of measures for tackling agriculture pressures under the EU WFD." http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/thematic_documents/wfd_agriculture&vm=detailed&sb=Title

Chapter 8

Asian Development Bank, 2005. *Climate Proofing: A Risk-based Approach to Adaptation*. Available online at: http://www.adb.org/Documents/Reports/Climate-Proofing/climate-proofing.pdf.

Australian Government, 2006. *Climate Change Impacts & Risk Management A Guide for Business and Government.* Available online at: http://www.climatechange.gov.au/impacts/publications/risk-management.html.

Callaway et al., 2006. *The Berg River dynamic spatial equilibrium model: a new tool for assessing the benefits and costs of alternatives for coping with water demand growth, climate variability and climate change in the Western Cape.* AIACC (Assessment of Impacts and Adaptations to Climate Change across Multiple Regions and Sectors) working paper no. 31. Washington, D.C., International START (Global Change System for Analysis, Research and Training) secretariat, AIACC. Available online at: http://www.aiaccproject.org/working_papers/Working%20Papers/AIACC_WP31_Callaway.pdf

Department for Environment, Food and Rural Affairs (Defra), 2008. *Future Water, The Government's Water Strategy for England*. Available online at: http://www.defra.gov.uk/environment/water/strategy/pdf/future-water.pdf.

ISDR and World Bank, 2008. *Mitigating the Adverse Financial Effects of Natural Hazards on the Economies of South Eastern Europe, a study of disaster risk financing options*. Available online at: http://www.unisdr.org/eng/about_isdr/isdr-publications/europe/Mitigating_Adverse_Financial_Effects_NH_Economies%20_SEE.pdf.

Mendelsohn, R., 2006. The role of markets and governments in helping society adapt to a changing climate. *Climatic Change* 78: 203–215.

Mills, E., 2007. From Risk to Opportunity: 2007, *Insurer Responses to Climate Change.* A Ceres Report. Available online at: http://insurance.lbl.gov/opportunities/risk-to-opportunity-2007.pdf.

Munich Re Group, 2008. *Highs and lows, Weather risks in central Europe*. Available online at: http://www.munichre.com/publications/302-05482_en.pdf.

OECD, 2008. *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments.* Available online at: http://www.oecd.org/document/2/0,3343,en_2649_34361_40691458_1_1_1_1,00.html.

Ofwat, 2008. *Preparing for the Future – Ofwat's climate change policy statement*. Available online at: http://www.ofwat.gov.uk/sustainability/climatechange/pap_pos_climatechange.pdf.

Ofwat, 2008. *Water supply and demand policy*. Available online at: http://www.ofwat.gov.uk/pricereview/pap_pos_pr09supdempol.pdf

Provention Consortium, 2006. *Global Index Insurance Facility (GIIF) Concept Note.* Commodity Risk Management Group, World Bank. Available online at: http://www.proventionconsortium.org/themes/default/pdfs/GIIF_overview_Feb06.pdf

Stern, N., 2006. *The Economics of Climate Change: The Stern Review.* Cabinet Office – HM Treasury, Cambridge University Press. Available online at: http://www.hm-treasury.gov.uk/stern_review_report.htm.

Swiss Reinsurance Company, 2003. *Natural catastrophes and reinsurance.* Available online at: http://www.swissre.com/resources/15a16b80462fc16c83aed3300190b89f-Nat_Cat_en.pdf

United Kingdom Environment Agency, 2008. Water resources planning guideline. Available online at: http://publications.environment-agency.gov.uk/pdf/GEHO1208BPDC-E-E.pdf

UNECE, 2006. R*ecommendations on Payments for Ecosystem Services in Integrated Water Resources Management.* Available online at: http://www.unece.org/env/water/publications/documents/PES_Recommendations_web.pdf.

UNFCCC, 2007. *Investment and financial flows to address climate change* Available online at: http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/background_paper.pdf.

UNFCCC, 2008. Investment and financial flows to address climate change: an update, Technical paper, FCCC/TP/2008/7. Available online at: http://unfccc.int/resource/docs/2008/tp/07.pdf.

Warner, K. N. et al., 2009. *Adaptation to Climate Change: Linking Disaster Risk Reduction and Insurance*. Available online at: http://www.preventionweb.net/files/9654_linkingdrrinsurance.pdf

Chapter 9

Burton, J.F. et al. (eds.), 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Available online at: http://www.decisioncraft.com/energy/papers/hbccia/.

Duda, A., 2002. *Monitoring and Evaluation Indicators for GEF International Waters Projects.* Monitoring and Evaluation Working Paper 10. Global Environment Facility. Available online at: http://www.gefweb.org/M_E_WP__10.pdf.

GWP-TAC, 2008. *Monitoring and evaluation indicators for IWRM strategies and plans*. Technical brief 3. Available online at: http://www.gwpforum.org/gwp/library/Tec_brief_3_Monitoring.pdf.

Perez, R.T. et al., 2005. Continuing the adaptation process. In: Lim B. et al. (eds.) *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Cambridge, United Kingdom, UNDP/Cambridge University Press.

Valencia, I. D., 2008. Lessons on M&E from GEF Climate Change adaptation projects. Presentation at the International Workshop on Evaluation of Climate Change and Development, May 2008.

PHOTO CREDITS:

Page iv UN Photo©Mark Garten
Page 12 IKSR Photo©Klaus Quauke
Page 19 IKSR Photo©Klaus Quauke
Page 24 UN Photo©Mark Garten
Page 26 UN Photo©Mark Garten
Page 27 UN Photo©Eskinder Debebe
Page 36 IKSR Photo©Klaus Quauke
Page 37 UN Photo©Mark Garten
Page 37 UN Photo©Eskinder Debebe
Page 39 IKSR Photo©Klaus Quauke
Page 42 UNECE©Yaroslav Bulych
Page 46 USGS©M.Nolan
Page 48 UNECE©Yaroslav Bulych
Page 49 Vaisala
Page 53 Vaisala
Page 54 ICPDR Tisza Group©Alexei Iarochevitch
Page 65 UNECE©Yaroslav Bulych
Page 70 UNECE©Yaroslav Bulych
Page 80 WWF-Canon©Anton Vorauer
Page 81 SDF partners, 2008
Page 90 Masaryk Water Research Institute©T.G. Oldrich Novicky
Page 93 Finnish Environment Institute©Markku Ollila
Page 97 UNECE©Yaroslav Bulych
Page 97 UN Photo©Mark Garten
Page 100 UNECE©Yaroslav Bulych

All other images used in this publication were provided by: Fotolia and Shutterstock Images

Convention on the Protection and Use of Transboundary Watercourses and International Lakes
Environment, Housing and Land Management Division
Economic Commission for Europe
Palais des Nations
8 -14 avenue de la Paix
1211 Geneva 10
Switzerland
Tel: 00 41 22 9172463
Fax: 00 41 22 9170107
E-mail: Water.Convention@unece.org
Website: http://www.unece.org/env/water/welcome.html

This publication is printed on 100 per cent recycled, chlorine-free paper.

Guidance on Water and Adaptation to Climate Change

Climate change will result in significant impacts on our water resources and some of the effects are already visible now. Nearly all the countries are expected to be negatively affected. Moreover, climate change impacts on water resources will have cascading effects on human health and many parts of the economy and society, as various sectors directly depend on water.

Adaptation to climate change is needed now and water management should be a central element in the adaptation strategy of any country. A particular challenge for water resources management is connected to the fact that almost half of the world's total land surface is drained by international river basins. As both water and climate change do not respect borders, transboundary cooperation in climate change adaptation is not only necessary to prevent possible conflicts due to unilateral adaptation measures, but also beneficial to enable more effective adaptation.

The Guidance on Water and Adaptation to Climate Change aims to spur climate change adaptation that takes into account the transboundary dimension of water management. It is a novel and innovative product which focuses on the transboundary setting and illustrates the steps needed to develop an adaptation strategy. Based on the concept of integrated water resources management, the Guidance provides advice to decision makers and water managers on how to assess impacts of climate change on water quantity and quality, how to perform risk assessment, including health risk assessment, how to gauge vulnerability, and how to design and implement appropriate adaptation strategies.

The Guidance places special emphasis on the specific problems and requirements of transboundary basins, with the objectives of preventing, controlling and reducing transboundary impacts of national adaptation measures and thereby preventing and resolving possible conflict. The Guidance also underlines the benefits of cooperation in adapting to climate change in transboundary basins: sharing the costs and benefits of adaptation measures, reducing uncertainty through the exchange of information, broadening the knowledge base, and enlarging the range of measures available for prevention, preparedness and recovery, thus allowing us to find better and more cost-effective solutions.

http://www.unece.org/env/water/

UNECE would like to thank the following partners for their contribution to the Guidance preparation:

Ministry of Transport, Public Works and Water Management

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

World Meteorological Organization
Weather • Climate • Water

World Health Organization
EUROPE

Printed at United Nations, Geneva
GE.09-24992–October 2009–3,370
ECE/MP.WAT/30
United Nations Publication
Sales No E.09.II.E.14
ISBN 978-92-1-117010-8