ICPDR Strategy on Adaptation to Climate Change

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Disclaimer

The data available in the ICPDR Strategy has been dealt with, and is presented, to the best of our knowledge. Nevertheless inconsistencies cannot be ruled out.

"Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change"

(IPCC Technical paper "Climate Change and water", June 2008)

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List of Acronyms

CIS	Common Implementation Strategy for the Water Framework Directive
CLIMATE-ADAPT	European Climate Adaptation Platform
DRB	Danube River Basin
DFRM Plan	Danube Flood Risk Management Plan
DJF	December/January/February
DRBM Plan	Danube River Basin Management Plan
EC	European Commission
EEA	European Environment Agency
EFD	European Floods Directive
EU	European Union
GCM	Global Circulation Model
GHG	Greenhouse gas
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel on Climate Change
JJA	June/July/August
LDRB	Lower Danube River Basin
MDRB	Middle Danube River Basin
RBD	River Basin District
RCM	Regional Climate Models
RBM	River Basin Management
RBMP	Danube River Basin Management Plan
SRES	Special Report on Emissions Scenarios
UDRB	Upper Danube River Basin
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive

SECTION I – Introduction and framework conditions

The following section provides a brief overview on background information and framework conditions relevant for the adaptation of water-related sectors of the Danube River Basin (DRB) to Climate Change.

1 Introduction

1.1 Background

Climate change is worldwide scientifically confirmed, inter alia by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[1]. Despite ambitious international climate protection objectives and activities, adaptation to climate change impacts is urgently needed. Water is, together with temperature, in the centre of the expected changes. Due to the fact that water is a cross-cutting issue with major relevance for different sectors, water is the key for taking the required adaptation steps. In the Danube River Basin, climate change is likely to cause significant impacts on water resources and can develop into a significant threat if the reduction of greenhouse gas emissions is not complemented by climate adaptation measures.

1.2 Mandate

Ministers and high-level representatives responsible for water management in the Danube countries and from the European Union endorsed in February 2010 the 'Danube Declaration'[2], which expresses the commitment to further reinforce transboundary cooperation on sustainable water resources management within the Danube River Basin, including adaptation to climate change.

In order to take the required steps on adaptation, the ICPDR was asked in the Danube Declaration to develop until 2012 a Climate Adaptation Strategy for the Danube River Basin. This strategy should be based on a step-by-step approach and encompass an overview of relevant research and data collection, a vulnerability assessment, ensure that measures and projects are climate proof respectively "no regret measures" and ensure that climate adaptation issues are fully integrated in the 2nd Danube River Basin Management Plan in 2015. The Danube Declaration therefore constitutes the mandate for the elaboration of the 'ICPDR Strategy on Adaptation to Climate Change'.

1.3 Relevance for 2nd DRBM Plan and 1st DFRM Plan

In 2000, the European Union adopted the EU Water Framework Directive (WFD). The directive requires water management according to the outlines of natural river basins. The ICPDR is the platform for coordination of the implementation of the WFD on the Danube basin-wide scale. The WFD is, together with the EU Floods Directive (EFD) from 2007, of highest priority for the ICPDR, as all its contracting parties, including non-EU countries, agreed to a coordinated implementation.

As a result of these efforts, the 1st Danube River Basin Management Plan (1st DRBM Plan) was developed based on the principles of the WFD and adopted by the ICPDR in 2009. It included first conclusions on the need for climate adaptation. According to the 6-years management cycle of the

[1] Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (2007): Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom and New York, USA.

[2] Danube Declaration: http://www.icpdr.org/main/sites/default/files/Ministerial%20Declaration%20FINAL.pdf

WFD, the Danube River Basin Management Plan will be reviewed and updated by the end of 2015 (2nd DRBM Plan). This is the same target date as for the elaboration of the 1st Danube Flood Risk Management Plan (1st DFRM Plan) according to the EFD, which will in future also be reviewed and updated in 6-years planning cycles.

Both directives and related management plans are key tools for the adaptation of the water sector to climate change, including the issue of water scarcity and droughts. The underpinning rationale and processes for the implementation of the WFD and EFD are as well applicable to approach the issue of climate adaptation. In particular, the integrated approaches to water and ecosystem management, combined with the cyclical review of progress achieved, are consistent with the basic principles of adaptive management what is specifically important for climate change adaptation. In addition, climate change impacts upstream can have implications downstream and vice versa. Therefore, international cooperation as part of the implementation of both directives plays an important role.

However, certain limitations have to be pointed out in terms of what can be delivered in the frame of the ICPDR on adaptation. These limitations are twofold, touching on one hand the level of detail which can be achieved in adaptive planning on the Danube basin-wide scale, on the other hand the relevance for different sectors concerned. A demarcation of action fields is therefore required along the lines the ICPDR can be active on. While the focus should be on integrative planning for the water sector on issues relevant for the basin-wide scale, more detailed planning has to take place on the sub-basin and/or national level, what may insofar deliver further detailed adaptation actions and strategies also covering non water-related sectors.

2 Framework conditions

2.1 Relevant water-related EU Directives and Policies

Several existing EU Directives and policies contribute to efforts for adaptation to climate change with regard to water issues. As indicated, the most important ones are the WFD (and its daughter directives) and the EFD, but also other policies like the Water Scarcity and Droughts EU Policy as well as the EC's White Paper on Adaptation are important building blocks for adaptation (see chapter 2.2). In the following, a brief overview on the WFD and EFD as the key tools for adaptation is provided.

2.1.1 The EU Water Framework Directive 2000/60/EC

The Water Framework Directive 2000/60/EC (WFD)[3] establishes a legal framework to protect and restore the water environment and to ensure the long-term sustainable use of water. Although climate change is not explicitly included in the text of the WFD, the step-wise and cyclical approach of the WFD river basin management process makes it well suited to handle climate change, what is explained in detail in the EU CIS Guidance No. 24[4].

Climate change should be comprehensively considered in the different steps of the WFD implementation and RBM planning and implementation process, such as characterisation, analysis of pressures and impacts, economic analysis, monitoring, design of the programmes of measures and the default and water body objective setting processes (see Figure 1).

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT

[4] European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in an Changing Climate. Technical Report, Nr. 40.

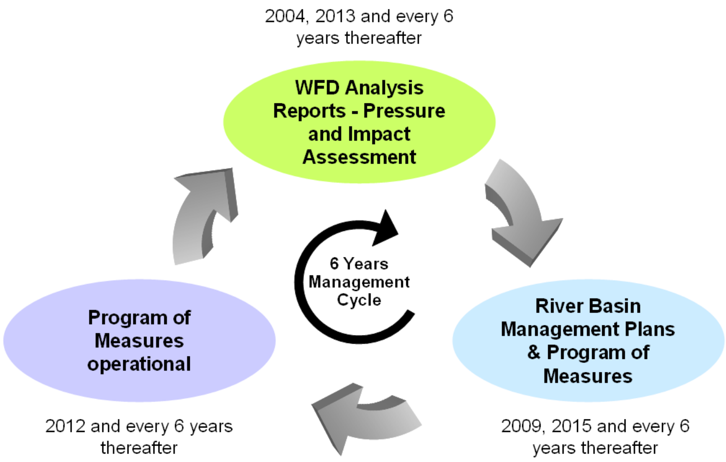


Figure 1: Main implementation steps EU Water Framework Directive

Climate change impacts may increase, but in some cases as well moderate pressures on water resources. Therefore, it is important that the next Danube River Basin Management Plans take account of the medium and long-term implications of climate change, as there is a large potential for synergies between objectives setting and adaptation aims. Thus the 2nd DRBM Plan due in 2015 should already be designed to be robust to the impacts of climate change and climate variability. As such, it must be ensured that measures are either flexible enough to be adjusted appropriately to changing climate conditions or that those of a fixed nature with a longer term design life incorporate climate projections in their design.

2.1.2 The EU Floods Directive 2007/60/EC

The EU Floods Directive 2007/60/EC (EFD)[5] establishes a legal framework for the assessment and management of flood risks, aiming at reducing the adverse consequences of floods to the human health, the environment, cultural heritage and economic activity. The Directive requires inter alia to elaborate the 1st DFRM Plan by 2015 for those areas where potential significant flood risk has been assessed. The Management Plan should provide adequate and coordinated measures to reduce this flood risk, taking into account the possible impact of climate change. The core elements of the flood risk management cycle are the preliminary flood risk assessment (accomplished for the Danube River Basin in March 2012), flood hazard and risk maps and flood risk management plans (see Figure 2).

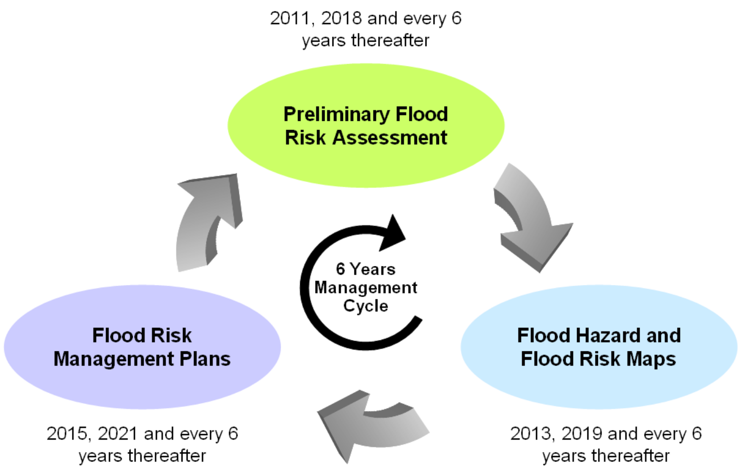


Figure 2: Main implementation steps EU Floods Directive

[5] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007L0060:EN:NOT

In contrast to the WFD, climate change is explicitly included in the Floods Directive. In particular the preliminary flood risk assessment shall include an assessment of the impacts of climate change on the occurrence of floods. In addition, for the implementation of the Floods Directive, co-ordination with the implementation of the WFD is required in order to ensure that differing and conflicting interests can be properly balanced and maximum synergies gained.

2.2 National and international adaptation activities

Besides the EU Water Framework Directive and the EU Floods Directive, several national and international activities are as well of relevance for climate adaptation in the Danube River Basin. National Adaptation Strategies focus on the assessment of the present situation and on the requirements for adaptation to climate change. They include suggested adaptation measures with regard to water related issues. Figure 3 illustrates the current status of adopted or planned National Adaptation Strategies. Most of the Danube countries have a National Strategy or are preparing one. This reflects the growing recognition of climate change impacts and the rising awareness for the necessity to adapt to climate change.

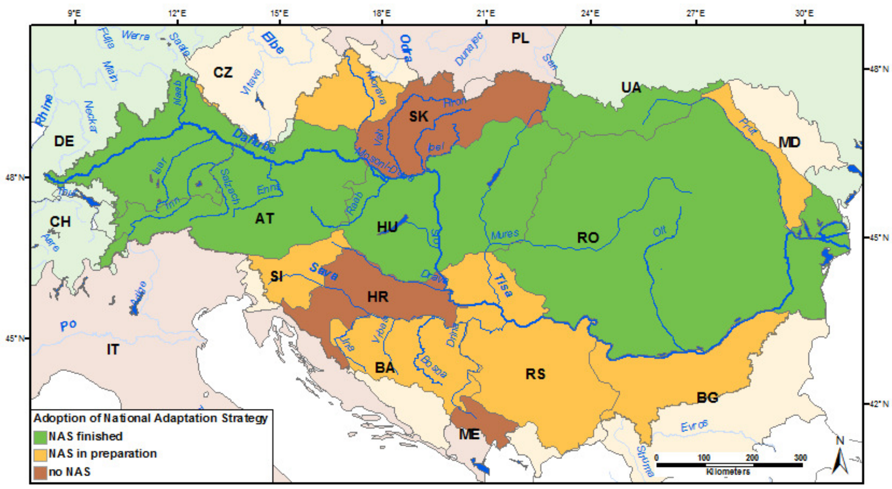


Figure 3: Overview of the current status of National Adaptation Strategies in the DRB (as of January 2012)

Additionally, National Action Plans for Croatia, Romania and Bulgaria as well as several national communications under the United Nations Framework Convention on Climate Change (UNFCCC) are important documents to serve, together with the National Adaptation Strategies, as basis for international coordination within the Danube basin.

At European level, the most important policy documents on adaptation to climate change for the water sector are the EC White Paper on Adaptation[6], the EU CIS Guidance No. 24[7], and the Blueprint to safeguard Europe's Water resources[8], beside the Guidance on Water and Adaptation to Climate Change[9], which was developed in the frame of the United Nations Economic Commission for Europe (UNECE). The European Climate Adaptation Platform CLIMATE-ADAPT is currently accessible under the domain name http://climate-adapt.eea.europa.eu (former EU Clearinghouse on adaptation). A short description of the most important documents is given in Table 1.

[6] European Commission (2009): Adapting to Climate Change: Towards a European framework for action. SEC (2009), Commission Staff Working Document, Impact Assessment, 287, 1-133.

[7] European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in an Changing Climate. Technical Report, Nr. 40.

[8] European Commission (2012): A Blueprint to safeguard Europe's Waters. http://ec.europa.eu/environment/water/blueprint/index_en.htm: [Accessed 02.07.2012]

[9] UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.

Document	Description
National communications under the UNFCCC	The national communications (5^{th} or initial)[10] provide an overview of present and future impact of climate change and adaptation measures on country level (and one at EU level).
EU White Paper (2009)	The EU White Paper "Adapting to climate change: Towards an European framework for action" calls for a more strategic approach to climate change adaptation across different sectors and levels of governance: inter alia to promote strategies which increase the resilience to climate change e.g. by improving the management of water resources and ecosystems, deliver adaptation action for flood risk, water scarcity and drought management and river basin management through catchment based approaches.
EU CIS Guidance No. 24 (2009)	The EU CIS Guidance document shows ways how to integrate climate change in the 2^{nd} and 3^{rd} River Basin Management (RBM) cycles of the WFD with a special focus on floods and droughts and on how to ensure that the River Basin Management Plans (RBMP's) are climate-proofed in 2015.
2012 Blueprint to safeguard Europe's Water resources	The overall objective of the Blueprint is to improve EU water policy to ensure good quality water, in adequate quantities, for all authorised uses. It will ensure a sustainable balance between water demand and supply, taking into account the needs of both people and the natural ecosystems they depend on. The Blueprint's policy recommendations will be based on the results of four ongoing assessments: 1. analysis of the WFD's river basin management plans (RBMP), 2. the review of the 2007 policy on water scarcity and drought, 3. the water's vulnerability to climate change and man-made pressures, 4. the outcome of the fitness check of EU freshwater policy. The 2012 Blueprint will be released by the end of 2012.
CLIMATE-ADAPT	The European Climate Adaptation Platform (http://climate-adapt.eea.europa.eu) provides information on expected climate change, current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies and potential adaptation options and tools that support adaptation planning.
UNECE Guidance on Water and Adaptation to Climate Change (2009)	The UNECE Guidance aims to support decision makers from the local 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.

Table 1: Important activities addressing the topic of adaptation

There are also a few further regional adaptation activities in parts of the Danube River Basin namely in the sub-basins of Sava and Tisza, the Danube-Delta as well as in the Alpine Space and the Carpathian Region.

2.3 ICPDR approach towards strategy development

Based on the mandate for the development of the 'ICPDR Strategy on Adaptation to Climate Change', the ICPDR decided to nominate Germany leading the activity in the frame of the ICPDR, with the River Basin Management Expert Group as the responsible ICPDR Expert Group following the issue.

[10] Link to Information on national communications under the UNFCCC

In support of the development of the Strategy, additional experts were nominated by the Danube countries, being involved and providing expertise during the elaboration process.

In its function as 'Lead Country' on the activity, the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supported a study with the aim of providing foundations for a common, Danube-wide understanding of future impacts of climate change on water resources and suitable adaptation measures as a basis for the development of the Danube Climate Adaptation Strategy. The 'Danube Study – Climate Change Adaptation'[11], including the main relevant impacts and fields of action, was developed by the Ludwig-Maximilians-Universitaet Munich (Department of Geography, Prof. W. Mauser) with involvement of experts and stakeholders from the Danube countries, and finalised in January 2012 (based on information available until June 2011).

The results of the Study were presented and discussed in the frame of the 'Danube Climate Adaptation Workshop', which was organised in March 2012 in Munich. The discussions and output of the workshop allowed taking the first steps in the development of the Strategy, which was subsequently further developed with broad participation of relevant ICPDR Expert Groups and Task Groups, including nominated experts and ICPDR Observer Organisations, during 2012.

2.4 General considerations

A basic principle which was followed during the elaboration process was to build the Strategy on best knowledge available. This is the case for the development of the 'Danube Study – Climate Change Adaptation' in particular, but also for the development of the Strategy in general. By building the Strategy on existing material, including for instance the EU CIS Guidance Document No. 24[12], the linkage to ongoing international processes on adaptation, specifically the EU process, is ensured.

The focus of the Strategy is clearly on issues relevant for the Danube basin-wide scale (level A), being in line with the mandate of the ICPDR and at the same time paying attention to the different levels of river basin management (level A, B and C) as requested by the WFD and EFD. Hence, further detailed planning on adaptation has to take place on the sub-basin, national and/or sub-unit level.

The main objective of the Strategy is to guide the way to fully integrate climate adaptation in the 2nd DRBM Plan and the 1st DFRM Plan. The Strategy therefore does not include a jointly agreed Programme of Measures on adaptation. The 2nd DRBM Plan and the 1st DFRM Plan will include Programmes of Measures which will integrate the issue of climate adaptation. This approach allows to make best use of the management plans required by the WFD and EFD as the key tools for adaptation. One particular advantage of this approach is that it also allows to make best use of knowledge and experience in place in existing ICPDR Expert and Task Groups, ensuring to deal with the high complexity of the topic.

[11] Prasch, M., Koch, F., Weidinger, R., Mauser, W. (2012): Danube Study - Climate Change Adaptation. Ludwig-Maximilians-University Munich, Department of Geography. Final Report (available on icpdr-website).

[12] European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.

SECTION II – Knowledge base

For adaptation to climate change the knowledge about the magnitude of climate change as well as the uncertainty about the magnitude of the effects of a changing climate is of major importance. In order to assess climate change impacts in the Danube River Basin and to identify appropriate adaptation measures, the "Danube Study – Climate Change Adaptation" analysed ongoing and finalized research and development projects and studies as well as adaptation activities. The study is based on best knowledge available as recommended in the CIS Guidance Document No. 24, was broadly discussed at the Danube Climate Adaptation Workshop held in Munich on 29/30 March 2012 and provides the main knowledge base for the elaboration of the adaptation strategy. The study is based on existing information available - no new modelling was carried out.

The following chapters provide information on the main results of the study. Further detailed information can be obtained directly from the study.

3 Climate change scenarios for the Danube River Basin

For the assessment of future climate parameters, various Global and Regional Climate Models are used. Over the course of time the models have been further developed in regard to coupled processes between different land surfaces, the atmosphere and oceans. Nevertheless, models are based on simplifications and assumptions. Despite careful validation, climate models sometimes over- or underestimate the investigated parameter compared to observed data. To determine climate change information from a global to a regional or local scale, different downscaling techniques are used. Furthermore, the underlying IPCC SRES[13] emission scenarios reflect only a range of possible developments, so the results of future simulations bear a certain degree of uncertainty.

Most of the future projections analysed within the "Danube Study – Climate Change Adaptation" are based on the IPCC SRES scenarios A1B and A2. The SRES scenarios cover a wide range of the main driving forces of future emissions as well as demographic, technological and economic developments.

A1B: A balanced energy production across all energy sources is reflected in the A1B-scenario embedded in the A1-storyline which describes a future world of very rapid economic growth, a global population that peaks in the middle of the current century, and the rapid introduction of new and more efficient technologies
A2: The A2-storyline describes a very heterogeneous world with a preservation of local identities and a primarily regionally oriented economic and technological development. Hence the global population is continuously increasing. The A2-scenario reflects a future with high emission rates (much higher than in A1B)

Table 2: Explanation of IPCC SRES A1B and A2 scenarios

The analysis of the future development shows for the climate parameters temperature, precipitation and its extremes different degrees in uncertainty. Projections of temperature values are very reliable due to the unambiguously results of the analysed projects. However, future precipitation patterns are more difficult to simulate, so the projected changes are not as robust as for temperature. The findings agree often in sign of changes but differ in magnitude. In some areas the results do not agree or are contrary. Changes are mainly described for 30-year future periods (mostly for 2021-2050 and 2071-

[13] SRES means "Special Report on Emissions Scenarios". The so called SRES scenarios cover 40 scenarios for the 4th (2001) and 5th (2007) IPCC report, developed from so called IS92 scenarios of previous IPCC reports. The 40 IPCC SRES scenarios are subdivided into 4 "scenario-families" A1, B1, A2 and B2.

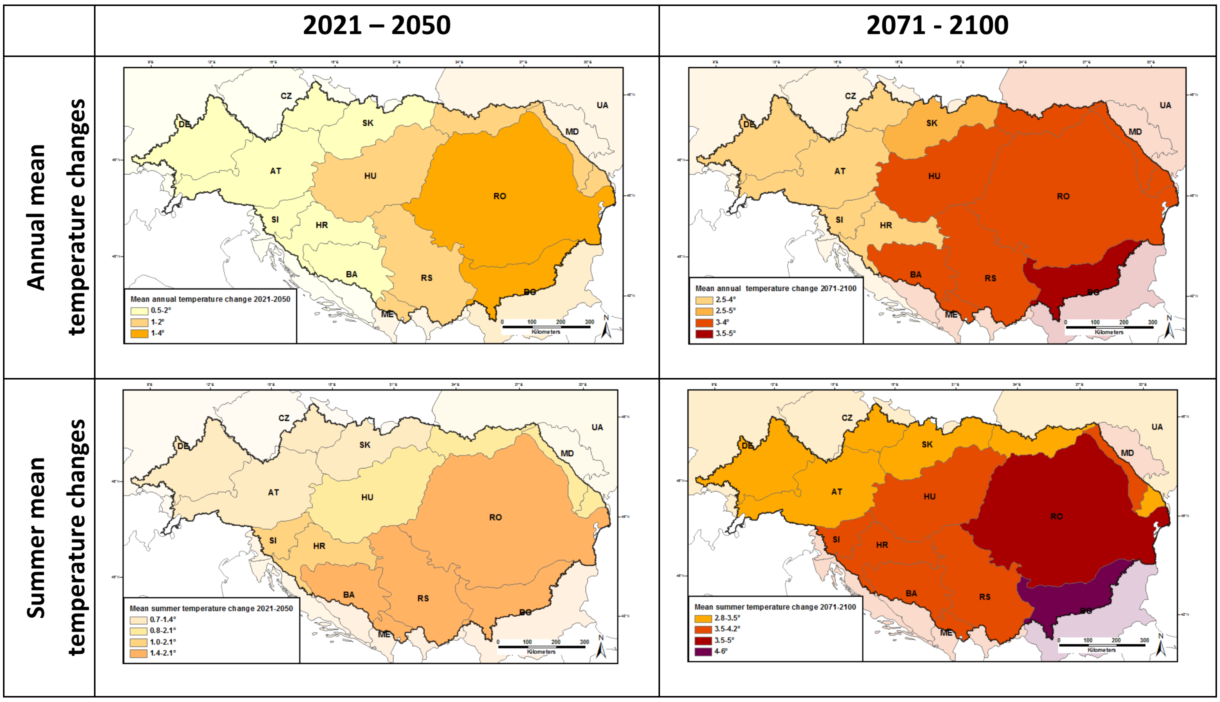
2100), but it has to be mentioned that within these periods there might be many years with precipitation or temperature amounts being just the opposite as they are anticipated by the general trend due to the natural variability of the climatic system. In the following, expected changes are described for both, SRES scenario A1B for the periods 2021-2050 and 2071-2100 as well as for the SRES scenario A2 for the periods 2010-2039 and 2049-2060. Furthermore, temperature and precipitation changes are described for meteorological seasons, whereas spring includes the months March, April and May, summer the months June, July and August, autumn includes September, October, November and winter the months December, January and February.

There is a general agreement in increasing extreme weather events in most parts of the Danube basin, but generally extreme events, especially heavy rainfall, are very difficult to model and therefore the results are linked with related uncertainties. Projected future changes are often described for the different countries. Therefore the examples of expected changes are illustrated on a country-by-country basis in subsequent Figure 4 to Figure 7. Of course, the values do not change abruptly at national borders.

3.1 Air temperature

For the Danube River Basin an increase of air temperature with a gradient from northwest to southeast, annually and in all seasons, is projected as main future trend (Figure 4). Particularly the south-eastern Danube region is expected to become much warmer than in the last decades. The mean annual temperature increase for the near future period (2021-2050) differs regionally between +0.5°C and +4°C. This tendency might intensify during the second half of the century with values between 2.5°C and 5°C at the end of the century.

Whilst in the near future period 2021-2050 the seasonal temperature increase might reach values between 0.7°C and 2.1°C, particularly the changes in mean summer temperatures in the period 2071-2100 are more distinct and can reach values of 2.8°C to 6°C. Nevertheless there are considerable local differences due to climate influencing factors like altitude, mountainous massifs, seas, lakes, lowlands, etc. However, the general increasing trend is very reliable due to the high correlation of many studies (see Figure 9). In all models the uncertainty is largest for winter.



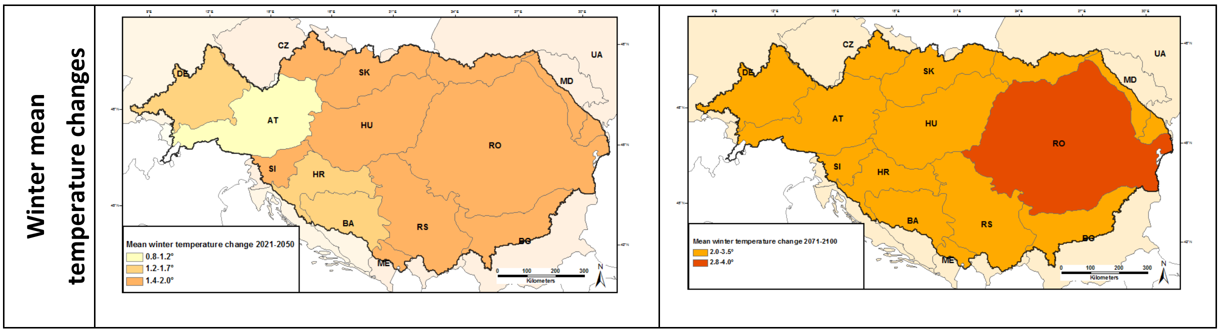


Figure 4: Change of mean annual , summer (JJA) and winter (DJF) temperature in the Danube River Basin for 2021-2050 and 2071-2100 according to A1B scenario of different model results

3.2 Precipitation

The Danube River Basin is located in the transition zone between expected increasing (Northern Europe) and decreasing (Southern Europe) future precipitation. This general trend is more obvious in the second half of the century as illustrated for the Danube basin in Figure 5. Although the mean annual values in many countries will probably remain almost constant, a tendency for the next decades to more precipitation (than in the last decades) in the northern parts of the basin and less precipitation in the southern parts is apparent.

The Alpine Space is divided into a wetter north and a drier south, especially the south-eastern part of Austria is likely to become drier. Also the distribution pattern of Romania is divided into a northern region (higher elevations in the Carpathian Mountains) with more precipitation and a southern region (lowlands) with less precipitation than today.

According to the analysed projects, regionally and seasonally large changes in future precipitation are projected for the 21st century. There is less information and no clear tendencies for spring and autumn, but multiple scenario results show future decreasing trends for summer (on average app. -15%, in some parts up to -30%) and a tendency for increasing winter precipitation (app. +5 to +20%, in some parts up to +35%) with, however, a high variability. The tendency for drier summers strengthens during the course of the century as shown in Figure 6. The results for the future trend of increasing winter precipitation are illustrated in Figure 7.

Naturally there are regionally opposing trends, e.g. in southern parts of the Alps, including Slovenia, where decreasing values for winter are simulated. In the Middle Danube Basin, esp. in Hungary, a reversal of seasonal precipitation distribution is often indicated in research results. This means that currently most of the precipitation falls during summer and the least during winter. The projected changes anticipate that this pattern will significantly change in the future with a more uniform precipitation distribution over the Upper and Middle Danube Basin.

Because the general trend is consistent in most simulations, the certainty-category for precipitation is high (see Figure 8), however, compared with air temperature, less robust and reliable. Different models produce partly contrasting patterns of the spatial distribution of precipitation and there are a lot of quantitative uncertainties in the changes of both, mean and extreme precipitation amounts.

Higher temperatures in winter affect the cryosphere. Instead of snow, it might rain more often and together with an earlier beginning of snow melt the snow cover is expected to decrease and so the snow season is getting shorter in all altitudes. However, some findings for mountainous areas state no trend or even a slight increase of snow fall due to a possible increase in winter precipitation. Glaciers show a significant retreat in the DRB. Climate change leads to the total disappearance of glaciers in all mountainous areas of the Middle Danube River Basin (MDRB). In the Alpine part of the Upper Danube River Basin (UDRB), only few small glaciers will be left in the far future.

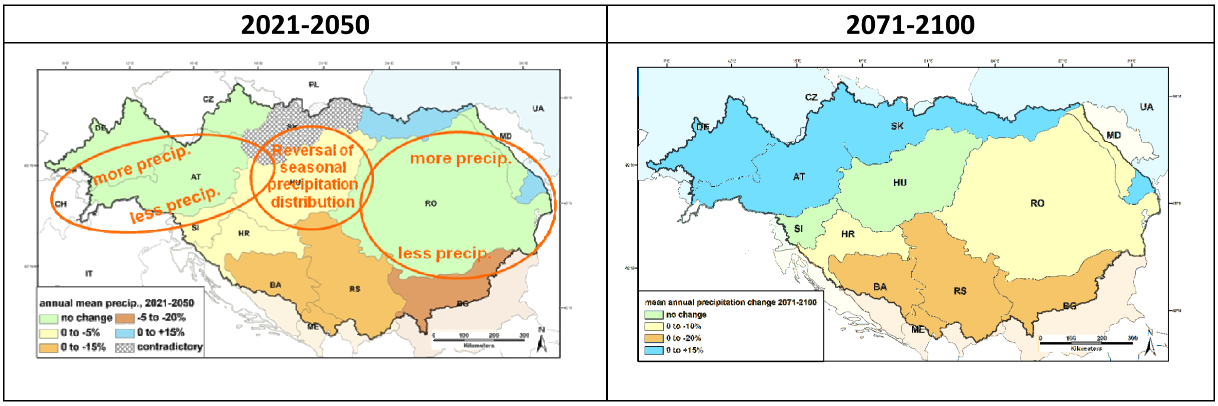


Figure 5: Change of mean annual precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to A1B scenario of different model results

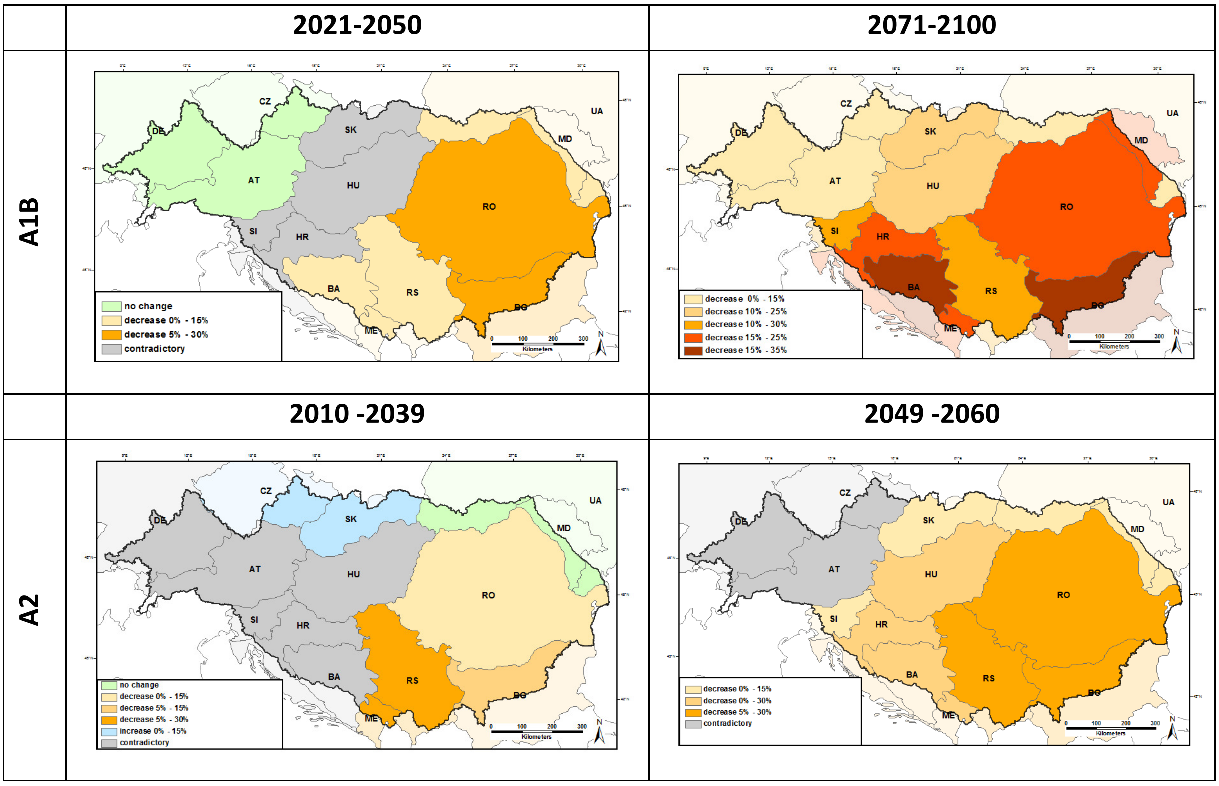
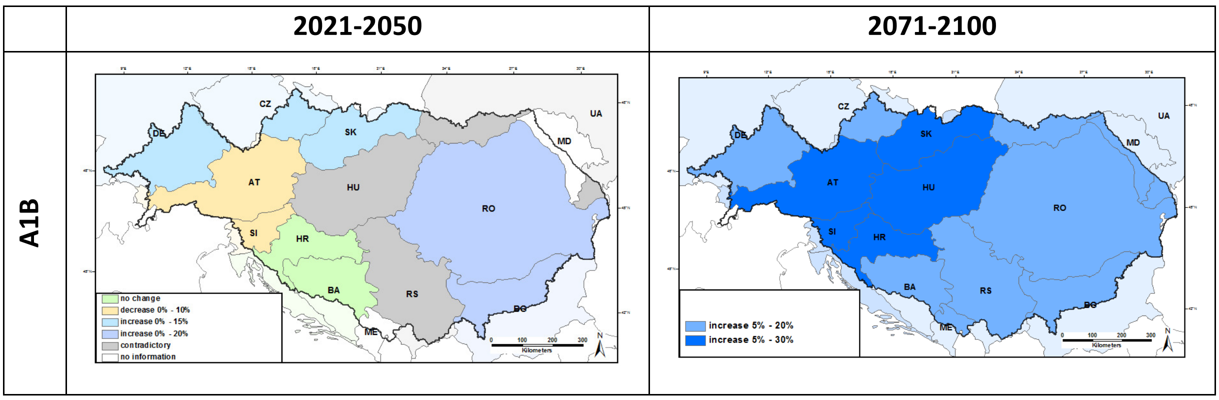


Figure 6: Change of summer (JJA) mean precipitation in the Danube River Basin for different periods according to A1B and A2 scenarios of different model results



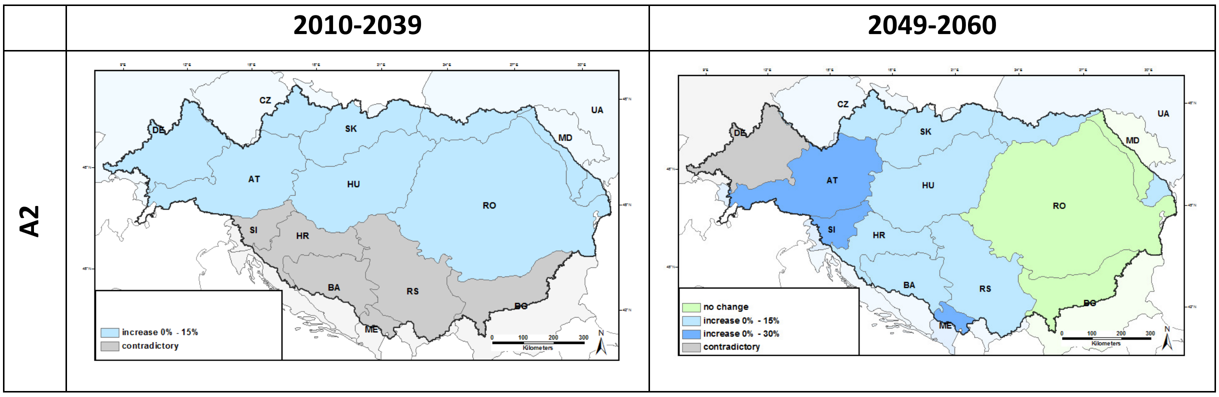


Figure 7: Change of winter (DJF) mean precipitation in the Danube River Basin for different periods according to A1B and A2 scenarios of different model results

3.3 Extreme weather events

A future increase of extreme weather events is expected for the whole DRB. The simulations show both a future increase in intensity and frequency of dry spells, hot days and heat waves as well as local and regional increases in heavy rainfall, but the latter is uncertain in spatial and temporal allocation. For the Upper Danube Basin an increased risk of storm-related heavy precipitation with high wind speeds is assumed. For the Middle Danube Basin it is of interest that the occurrence of extreme precipitation days will be intensified in winter and reduced in summer. Due to the warming trends for the whole basin fewer frost days in winter are expected.

4 Water-related impacts of climate change in the DRB

4.1 Uncertainty

Many different factors are influencing the certainty of the statements about climate projections and climate change related impacts on the water sector analysed in the "Danube Study – Climate Change Adaptation". Figure 8 summarizes the main factors, which lead to different levels of uncertainty of these statements. They are further described in detail, more or less clockwise beginning at twelve.

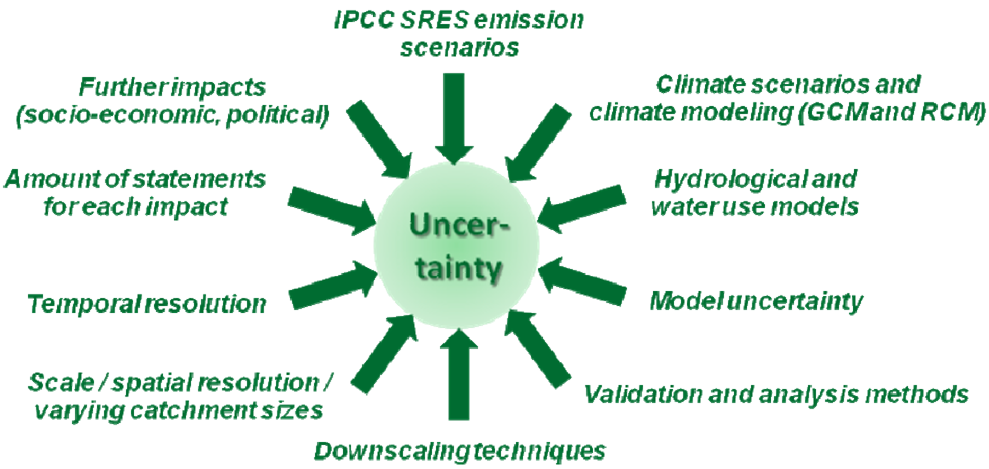


Figure 8: Main factors influencing uncertainty in climate change analysis

For climate change projections, different possible future assumptions (inter alia on the emissions of greenhouse gases and the socio-economic development), reflected by various IPCC SRES scenarios, serve as a basis (see Chapter 3). However, for the same SRES scenario the outcomes of different climate models are diverse because the models represent the climate process in different ways. Generally, each climate and hydrological projection is subject to limitations in the ability to model the climate and water-related system. Even in case some projects use the same Global Circulation Model (GCM) they can differ in further applications like regional modelling and downscaling techniques. In the Danube countries different Regional Climate Models (RCM) and in the several catchment areas different hydrological models are used. Only a few projects use a water-use model, which can compute both water use and availability on a river basin scale.

Also for validation and analysis of the projections different methods are applied. Downscaling techniques were used to get climate change information from a global to a regional and local scale. In addition to these different methods the findings often differ widely in relation to space and time, so they finally could not simply be compared and summarized. For each issue (see Chapter 4.2) a different number of projects and studies were available. For some impacts only very few statements were available whereas for others a high amount of studies could be analysed. But a high amount of available studies does not automatically imply a high agreement of their findings. Finally, climate change is accompanied by other influences like political or socio-economical impacts.

To give “uncertainty” respectively “certainty” a tangible form, three variables are used in the Study to determine a certainty category for climate parameters and impacts: 1. certainty of statements, 2. level of agreement of different statements and 3. the amount of analysed studies. The first and second variables are assigned to one of eight values within the range 0.5 and 4. The third variable is a real number, coded in eight categories. Further details are described in the “Danube Study”.

Figure 9 gives a pragmatic overview of the certainty of each climate related impact in the Danube River Basin due to the analysis of projected changes. If the amount of the projects considering one special impact is large and the agreement and certainty assessment is high, the certainty-category indicates a high overall certainty such as for temperature. However, if the amount of projects is high but the agreement or the certainty assessment of the statements and results is low, the certainty-category shows a medium-ranged overall certainty.

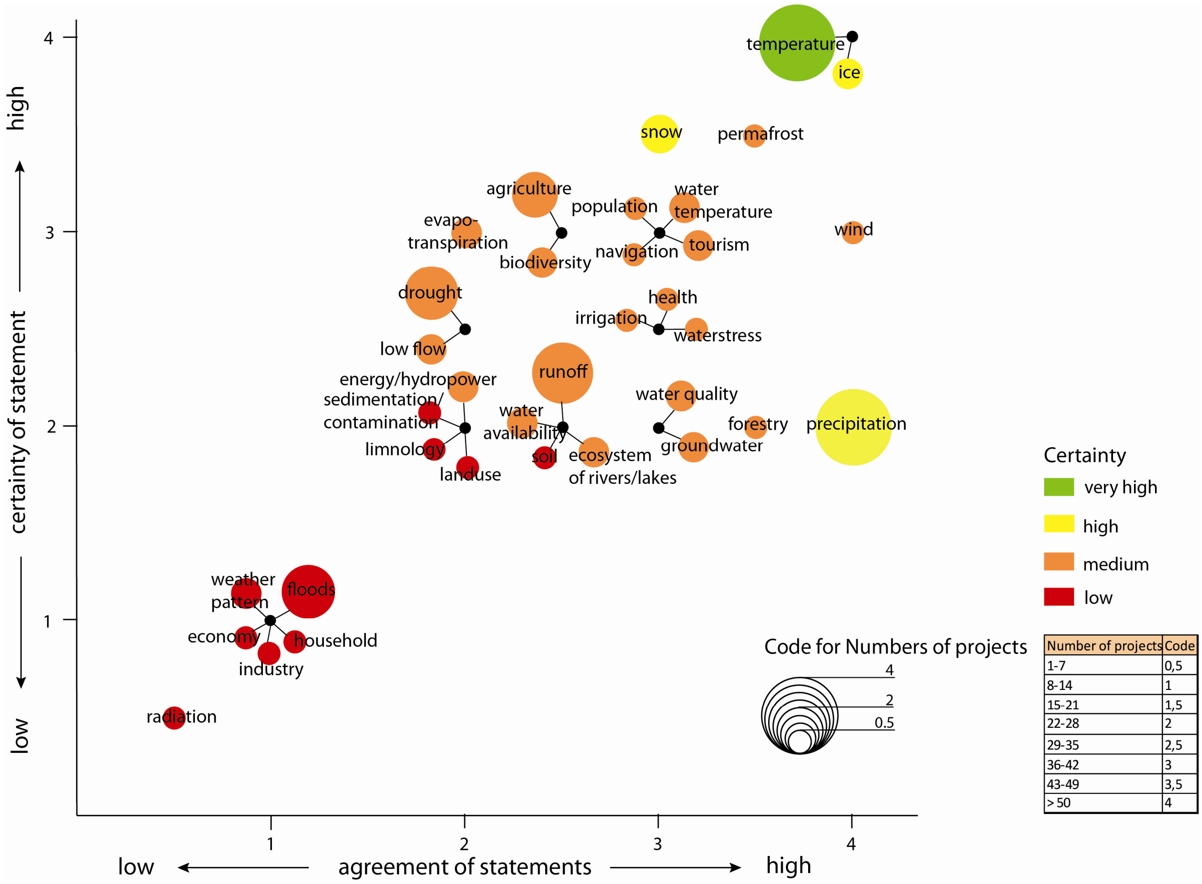


Figure 9: Overview of certainty for the impacts in the Danube River Basin due to projected climate changes

The certainty of the projections of temperature and precipitation are high and, due to the above mentioned factors, the certainty of water- and temperature-related impacts show mostly a medium certainty. Some of them tend to a higher category as for example agriculture, runoff and drought. The certainty category indicates for the most analysed sectors that changes are highly to be expected and adaptation measures should now be required in water management.

The overall level of certainty should be taken into account in the development of future adaptation measures. A high level of certainty may allow to prepare adaptation measures at an early stage and/or more detailed whereas a low level of certainty may lead to a more general type of measures (e.g. no-regret measures or win-win solutions).

Of high interest in many sectors are future flood events as well as droughts and low flow situations. Therefore, for these examples the classification and hence the interpretation of the certainty category are explained in more detail. As can be extracted from Chapter 2.2, flood risk management is often addressed by adaptation activities. However, the certainty of flood projections is low. This is because within the analysed projects (amount=33) the agreement is very weak (see Figure 9). The findings on future development of flood frequency, esp. for the one-hundred-year flood (HQ_{100}) differ widely. The certainty of the statement is rated as low (Code 1), because flood events are triggered by many factors as temperature, precipitation, atmospheric conditions, runoff, routing, and snow melt. The future development of these factors is partly not clear. Additionally, precipitation driven flood events are mainly short-term events and occur locally. So floods are difficult to simulate by models, esp. for small catchment areas due to partly poor spatial and temporal resolution of precipitation data. Improvements like the implementation of "rain-on-snow events" and the capture of soil water content by models are important for more reliable statements.

Despite of less analysed projects for droughts and especially for low flow situations the certainty category is higher than for floods, namely medium. This is because the model results were mostly consistent, only for alpine areas there are few contradicting findings (agreement code 2). Especially in summer and in the south-eastern parts of the DRB droughts and low flow situations are expected to increase. Though the simulation of extreme events is generally less certain than for average situations (e.g. mean annual precipitation), modelling of medium- to long-term events such as droughts is more certain than short-term events like floods due to the temporal resolution (certainty code 2.5).

Perspectives of future uncertainty reduction through science

Not all of the factors influencing uncertainty are determined by a current lack in scientific knowledge. The natural short term weather fluctuations as well as the uncertainty about the assumed future greenhouse gas emission scenarios create ambiguities, which cannot be reduced by an increase of scientific knowledge. Therefore the discussion on the formulation and choice of suitable scenarios should be segregated from the uncertainty discussion and treated independently.

Science can, however, further reduce the uncertainty of the results of a scenario simulation by improving the skills of global and regional climate modelling as well as of the diverse climate impact models over the next decades. This will most likely be achieved by replacing current model parameterizations, which are based on past statistical relations, by first order science principles in current climate and impact models. In the meantime considerable uncertainties can be expected to prevail. This calls for evaluating and quantifying these uncertainties thoroughly and finding scaleable adaptation measures that can be adjusted as new evidence arises.

4.2 Overview on the main impacts

Besides the already mentioned regional and seasonal temperature and precipitation changes expected in the course of this century, the direct and indirect effects of these changes are of essential interest. This includes impacts on different fields related to water availability, extreme hydrological events, water quality, water and land use, and ecology. Despite the high heterogeneity and the often low comparability of the project results, the expectations of future climate conditions and the related impacts show mostly similar trends. Hence, only qualitative information can be given for the different impact fields instead of quantitative or probabilistic statements. For the main fields the expected impacts are listed in the following tables.

Water availability	
For the next decades a decrease in water availability for the southern and eastern parts of the DRB is indicated, whereas in the northern and western parts no trend or even a slight increase is projected. Changes in water availability can highly differ locally or regionally. This may result in medium up to severe water stress in the MDRB and in severe water stress in the Lower Danube River Basin (LDRB). Because of generally high water availability in the UDRB, water stress is expected to remain low in the UDRB.	
Runoff	Runoff seasonality shows a future increase of the mean discharge in winter and a decrease in summer for the entire DRB. Seasonal changes may differ locally. Main reasons are changes in precipitation and the snow (and ice) storage. A decrease in snow precipitation and accordingly in snow cover together with an earlier snow melt causes a shorter snow season in all altitudes and will in turn lead to a shift of the runoff regime. In head watersheds of the Alps and the Carpathian Range, this will cause a shift of the peak runoff from early summer to spring with an increasing risk of floods also in the surrounding lowlands. An increase in glacier melt has only relevance for the summer runoff situation in the head watersheds and has almost no influence on the runoff regime of larger river systems.
Snow/Ice/ Permafrost	Decrease of water storage in form of snow and ice. A further retreat of permafrost in mountainous regions will lead to a higher frequency of rock falls, other natural hazards and more sedimentation in rivers.
Groundwater	A general decline in groundwater storage and recharge for Central and Eastern Europe, especially in summer, is assumed. Besides shortages in water availability, a

	decline in groundwater recharge could also draw negative effects on groundwater quality. Additionally, a possible increase in irrigation using groundwater resources could intensify the decline. Pointing out regional differences, a pronounced decline is particularly indicated for the Hungarian Great Plain Area, which was monitored already in the past. For some Alpine regions, however, a local increase in groundwater storage is likely to occur.
Evaporation	Mean annual potential evaporation will increase due to warmer temperatures in all regions of the DRB, especially in summer, what can even lead to an acceleration of water stress. In regions with low water availability like the south-eastern parts of the DRB, actual evaporation will decrease, especially during dry periods, because less water is available to evaporate or transpire through plants.

Table 3: Expected impacts on water availability

Extreme hydrological events	
In general, it is less reliable to model the future development of extreme hydrological events like floods than changes in the average water balance. This is especially the case at the local scale. So the assessment of future floods includes a high uncertainty. Extreme weather events have sometimes a significant impact on hydrology. So torrential rainfall might cause a flash flood and a dry and hot period may cause a drought situation. Since extreme weather events are expected to become more frequent and intense so do extreme hydrological events. But the main causes are the expected future changes of temperature and precipitation patterns. Anthropogenic developments (e.g. land use changes, silting up of flood plains, overgrowth of flood channels by vegetation or river regulations) will influence future flood appearances.	
Drought/ Low flow/ Water scarcity	Within the DRB, drought and low flow events as well as water scarcity situations are likely to become more intense, longer and more frequent. Thereby, the frequency could increase especially for moderate and severe events. Due to less precipitation in summer these extreme events will occur more frequently in summer than in winter. In some parts of the DRB, the drought risk is expected to increase drastically in the future, leading to possible economic loss, potentials for water conflicts and water use restrictions. The Carpathian Area, particularly the southern parts of Hungary and Romania as well as the Republic of Serbia, Bulgaria and the region of the Danube Delta are likely to face severe droughts and water stress resulting in water shortages. In Alpine areas, e.g. some parts of Austria, no clear trend or even a slight improvement of the mean annual low flow and drought situations were identified. Therefore alpine head watersheds remain important for downstream areas during drought periods. The future low flow situation depends also on changes in water use, which could worsen or improve the general trend.
Flood	There is no clear tendency in the development of future flood events for the DRB as a whole. Within the basin there are different local tendencies, especially for the development of extreme flood events. An increase in flood intensity and frequency is likely to occur with emphasis on small and medium flood events, especially in alpine regions in late winter/spring triggered by changes in winter precipitation and snow storage.
Flash flood	Short-term flood events may occur more frequently. For small catchments an increase in flash floods due to more extreme weather events (torrential rainfall) is expected, e.g. in the Carpathian Range or the Sava and Tisza headwaters.

Table 4: Expected impacts on extreme hydrological events

Water quality	
Following the future increase in air temperature, water temperature will most likely increase in the DRB. Due to changes of all temperature dependent chemical and biological processes as well as increasing flood and drought events, the pressure on water quality in rivers and lakes increases.	
Water temperature	Exact numbers differ regionally and locally, but 1-2 K are often mentioned, particularly of surface waters and groundwater in summer. Freezing periods in winter are most likely reduced and the ice cover on lakes and rivers might decrease.
Water quality	Water quality is expected to be reduced, e.g. by a decreasing oxygen concentration in rivers, aquifers and lakes. Increased algal bloom can appear with higher water temperatures. More frequent flooding and flash floods can cause a higher mobility of particle-associated pollution and changes of the redox balance of inorganic compounds can cause release of organic colloids. After long droughts of particular relevance in groundwater protection zones are the so-called preferential flow paths along which pollutants can pass rapidly and almost unimpeded into groundwater[14].

Table 5: Expected impacts on water quality

Water use / Land use	
Climate change might affect all types of land use. An intensification of extreme events like floods and droughts leads to high impact on agriculture, forestry, industry as well as on built-up areas and infrastructure. As a consequence of decreasing water availability, a shortcoming in water supply is expected. An increased risk for conflicts over water use can occur in case no adequate adaptation measures are taken. Possible consequences are difficulties in water supply with an increased risk of water shortages and an over-exploitation of aquifers in the future. Besides climate change impacts, future water demand is also triggered by anthropogenic impacts and political regulations and restrictions as well as new technologies.	
Water supply	An assumed general increase in water demand for households, industry and agriculture together with the pronounced water scarcity during summer in the Lower and Middle Danube Basin and in some areas of the UDRB is likely to lead to high water stress. Industrial production losses during droughts and hot summers due to scarce water supply as well as higher difficulty and cost of using water resources are possible.
Water demand	Due to a warmer climate a higher water demand and water withdrawal for agriculture, industry, energy and human consumption is probable, especially in the southeast of the DRB and in the hot season. This includes enhanced water use for example for garden watering and field irrigation, more frequent showers and cooling water for plants.
Agriculture	Because of warmer and drier summers, water demand for livestock and irrigation can become higher. Additionally the appearance and development of pests and diseases can increase. The UDRB might benefit from a longer growing period, but in the MDRB and especially in the LRDB a shortening of the growing season with yield losses is expected. Due to more unstable weather conditions the inter-annual variability of crop yields increases, so that farmers will have higher economic risks.
Irrigation	Irrigation for agricultural purposes is likely to increase in the entire DRB, which can especially occur in the south-eastern parts due to an expected expansion of droughts during the growing season in the future. An increase may deteriorate the

[14] Preferential flow: Transfer of water and dissolved substances through the soil into the groundwater along root traces, wormholes and drying cracks.

	ecological and chemical balance of freshwater bodies and could lead to an increase of contaminated surface and groundwater bodies after enhanced agricultural use.
Navigation	More frequent limited or impassable navigation conditions are expected due to more frequent extreme water levels and unstable conditions, especially on routes comprising free-flowing river reaches. Higher future temperatures in winter have a positive effect because of less frost and icing. Low water levels lead to reduced cargo and limited navigability. This is stressed for the MDRB countries Slovakia and Hungary, especially in summer for the hot lowlands with less precipitation in future. The development of the navigability in the MDRB is also depending on climate change impacts in the upper area. For the UDRB a significant reduction of the minimal low water level and only little influence for shipping due to future high water projections is expected.
Hydropower	Future mean annual and mean summer hydroelectric power generation is likely to decrease in the DRB, although increases can occur in winter due to changes in water availability. However, the dimension is expected to differ regionally and locally, and depends inter alia on the type and strategy plans of each hydropower station. The decline of the mean annual and mean summer production values can be especially pronounced in the south-eastern parts. Particularly in mountain areas, a possible seasonal shift due to changes in precipitation and snow cover with a more balanced production over the year is expected.
Thermal electricity production	Possible temperature loads might increase and become problematic in the future. Thermal power stations using cooling water are seriously affected if water becomes warmer and additionally the amount of available water decreases.
Forestry	A lower productivity and health status of forests due to an increase in droughts is possible, especially in the southeast. However, due to higher annual temperatures, the length of the growing season might be extended and elevated atmospheric CO_2 concentrations can have a fertilising effect. Changes in the distribution, density and biodiversity of forests are also assumed. Forests might be impacted by an increasing risk of damages by forest-weakening pests (e.g. bark beetle), storms and forest fires. Cold and snow-related damages are likely to become less common, but otherwise an increase in spring frost damages is possible.

Table 6: Expected impacts on water use / land use

Ecology	
An increase in air and water temperature as well as changes in precipitation, water availability, water quality and increasing extreme events like floods, low flows and droughts might lead to changes in ecosystems, lifecycles, and biodiversity in the DRB in the long term. Especially the habitats and ecosystems in the south-eastern region of the Danube River Basin and in the Hungarian Great Plain area are likely to become drier and more fire accidents might occur.	
Biodiversity	Migration patterns are expected to expand north-eastwards and to higher altitudes, whereby a rearrangement of biotic communities and food webs and an earlier onset of lifecycles could take place. Certain species will likely face extinction. While mainly native species are expected to disappear, invasive species might increase.
Ecosystems	Especially in the MDRB and LDRB higher stress on aquatic ecosystems, especially on littoral communities and fish might occur. Shifts and changes of aquatic and terrestrial flora and fauna are expected. Some aquatic systems show a higher risk of algal blooms and eutrophication, indicating an endangerment of lakes and wetlands.
Soils/Erosion	Nearly all regions of the DRB show a possible decrease of soil water content. Longer dry soil periods are predicted especially for the MDRB and LDRB regions

	during summer droughts. Thereafter, in these regions soil degradation is also possible. Changes in precipitation patterns and an increase in torrential rain and flash flood events can lead to more intense soil erosion. An increase in soil temperature affects especially physical, chemical and biological processes of the top soil layers. Sedimentation in river system is likely to increase due to more extreme events and thawing permafrost.
Limnology	The water temperature of the top lake layer will increase remarkably. This could lead to changes of the lake stratification and its energy balance. Especially in summer, a decrease in lake levels is possible.
Marine coastal zones	Increasing sea surface temperatures could lead e.g. to redistribution and losses of marine organisms and an increase of invasive species as well as an increase in toxic bloom events. Rising sea levels could trigger coastal erosion with damages of buildings and a retreat of the inland coast as already monitored in the Danube Delta and the Romanian coastline to the Black Sea. Higher sea levels will likely increase salinization of estuaries and land aquifers with saltwater intrusions and will reduce coastal protection of dams and quay walls.

Table 7: Expected impacts on ecology

5 Vulnerability

5.1 The IPCC concept of vulnerability, the challenges and the added value of a vulnerability assessment

In the context of climate change the commonly used concept of vulnerability is the definition given by the IPCC. It defines vulnerability to climate change as 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 2007).

Following this definition a vulnerability assessment includes the character, magnitude and rate of climate change and climatic variations to which a system is exposed (*exposure*), the system *sensitivity*, and its *adaptive capacity* (IPCC, 2007)[15].

[15] IPCC, 2007, Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability, Cambridge University Press, Cambridge

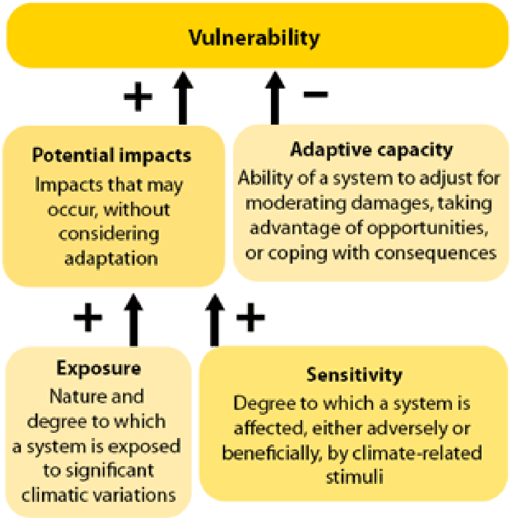


Figure 10: Key factors of vulnerability[16]

The methodological challenge for an assessment that aims at estimating future vulnerability to climate related impacts (e.g. for 2050) is to 'foresee' the future system, to estimate the sensitivity of this future system and to include the adaptive capacity of that system. The description of potential future climate change conditions (exposure) is usually not the bottleneck since data is available from scenarios and models.

Definition of keywords	
Vulnerability	The extent to which a system or actor is susceptible to, or incapable of coping with the detrimental consequences of climate change, including climate variability and extremes. Vulnerability depends on the character, magnitude, pace and variability of the climatic change to which the system is exposed, as well as the sensitivity and adaptive capacity of the system or actor.
Exposure	The degree of climate stress upon a particular unit or system; it may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events.
Sensitivity	The degree to which a system or actor is either adversely or positively influenced by climate variability or climate changes.
Adaptive capacity	The capabilities, resources or institutional capacities of systems, organisations or (individual) actors that enable them to adapt to climatic conditions that have altered or will alter in future and their possible impacts. Adaptive capacity includes to take effective adaptation measures and, by these means, to reduce potential damages, to take advantage of opportunities or to cope with the consequences, mainly by reducing its sensitivity by adaptation measures. To estimate the adaptive capacity, socioeconomic conditions and future developments need to be investigated, which is often done by scenarios and expert judgment.

Table 8: Key terms (following the IPCC's definition) associated with the topic of adaptation

The added value of an encompassing vulnerability assessment - depending on its spatial and temporal scope - is that it can help to determine specific regional or sectoral hot spots of vulnerability as well as to design suitable adaptation measures. In addition, such a vulnerability assessment enables a comparison and thus a prioritisation of adaptation needs and potentials and allows for a more

[16] http://www.cifor.org/fileadmin/subsites/cobam/images/cobam-e5.gif

informed or strategic allocation of resources. However, it must be clear that this assessment approach is complex, time and resource intense.

To create awareness for adaptation needs and to come to a common evidence base especially at a rather early stage of the adaptation process, usually a less complex impact analysis – without considering socioeconomic changes and adaptation efforts – is a helpful first step.

5.2 Approach for the Danube River Basin

Currently, no consistent and homogenous vulnerability assessment, neither qualitatively (descriptive) nor quantitatively (based on indicators) exists for the Danube River Basin as a whole. In Germany (2005) and Austria (2010), qualitative or semi-quantitative vulnerability assessments have been conducted. Quantitative assessments have been carried out within INTERREG-projects or European research projects mostly covering only parts of the Danube River Basin.

The most comprehensive studies covering larger parts of the Danube River Basin are the ESPON Climate[17] and the ClimWatAdapt[18] projects. Both studies have been analysed as part of the "Danube Study – Climate Change Adaptation" and their results have been integrated in the overview given in Chapter 4. Because both studies cover greater parts of Europe they are not normalized for the Danube River Basin. Thus an extraction of results for the Danube River Basin needs to be interpreted with care.

ESPON Climate covers the European Union territory of the Danube River Basin. The results of ESPON Climate for South-Eastern Europe show "hot spots" in regards to flooding for Hungary and Slovenia. In other regions of the Danube River Basin decreasing precipitation might even lead to decreases in flood related impacts. Environmental and economic impacts due to a hotter and drier climate are expected to be medium to high in most of South-East Europe. In these regions also the adaptive capacity was estimated to be rather low thus resulting in high levels of vulnerability.
ClimWatAdapt covers the whole Danube River Basin. It focuses on river floods, water scarcity and droughts. In general it shows that in future the amount of population endangered by floods varies largely between the regions. Highest potentials for health and economic damages are expected in Bosnia and Herzegovina. Annual as well as summerly water stress will mainly influence Serbia, Romania and Bulgaria, also due to an expected increase in withdrawals, which can be counteracted by sustainable water management. Otherwise water stress will aggravate the competition for water between households, tourism, industry, agriculture, and nature.

Table 9: ESPON Climate and ClimWatAdapt projects

To facilitate the basin-wide coordination of adaptation measures and their prioritisation, a spatially detailed, consistent and homogeneous (quantitative or semi-quantitative) vulnerability assessment for the Danube River Basin would be a helpful instrument and may be a future step in the basin-wide adaptation process. However, for the preparation of the 2nd DRBM Plan and 1st DFRM Plan it does not seem to be a feasible option, taking into account the necessary resource input and expectable added value.

As a first step towards a vulnerability assessment the existing impact analysis (see Chapter 4) is well set to create a common understanding and knowledge base and to raise awareness about current and

[17] Greiving, S. et al. (2011): ESPON CLIMATE - Climate Change and Territorial Effects on Regions and Local Economies. Applied Research Project 2013/1/4. Final Report. Dortmund. Available at: http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/climate.html

[18] Flörke, Martina, Florian Wimmer, Cornelius Laaser, Rodrigo Vidaurre, Jenny Tröltzsch, Thomas Dworak, Natasha Marinova, et al. 2011. Climate Adaptation – modelling water scenarios and sectoral impacts. Final Report. Center for Environmental Systems Research (CERS) in cooperation with Ecologic, Alterra and CMCC. Available at: http://www.climwatadapt.eu/

future challenges connected with climate variability and change. In addition, water related effects of climate variability known from national climate adaptation strategies as well as the results of national vulnerability assessments should be taken into consideration by the relevant ICPDR Expert Groups and Task Groups during the preparation of the 2nd DRBM Plan and the 1st DFRM Plan.

6 Overview on possible adaptation measures

Following the UNECE Guidance[19], climate change impacts on water resources should always be considered together with other pressures or stressors like population growth or changing consumption patterns when planning adaptation measures. So adaptation measures with respect to climate change can often build upon on planned or already implemented water management measures. Adaptation planning in general should consider and prevent possible conflicts and provide adequate tradeoffs.

Although the statements on climate change bear a certain degree of uncertainty, adaptation should start now with a priority on win-win, no-regret and low-regret measures to be flexible enough for various conditions. But also the adaptive approaches require flexibility within the management framework to modify if new information and understandings become available. This way of working has the benefit to increase resilience and to decrease vulnerability of the whole Danube ecosystem. For a common understanding of some keywords the definitions are given in Table 10.

Definition of keywords	
Adaptation	Adaptation refers to actions that people take in response to, or in anticipation of projected or actual changes in climate, to reduce adverse impacts or take advantage of the opportunities posed by climate change.
Mitigation	Mitigation refers to actions taken to prevent, reduce or slow climate change, through slowing or stopping the build-up of greenhouse gases in the atmosphere.
Win-win measures	Cost-effective adaptation measures that minimize climate risks or increase adaptive capacity but also have other social, environmental or economic benefits; 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.
No-regret measures	Cost-effective adaptation measures that are worthwhile (i.e. they bring net socio-economic benefits) whatever the extent of future climate change is; include measures 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.
Low-regret measures	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.
Climate-proof	Activities to increase the resistance and resilience of the policies, plans and programs that will be directly or indirectly affected by the impacts of climate change, acknowledging the new conditions where the baseline is inherently unstable and changing, and including climate protection aims.

[19] UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.

Resilience	The resilience of a natural system is the capacity of this system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient system can withstand shocks like extreme events and rebuild itself. When a system loses resilience, it becomes vulnerable to changes that previously could be absorbed. In a vulnerable system, even small changes may be devastating. Even in the absence of disturbance, gradually changing conditions such as climate, land use and policies can surpass threshold levels, triggering an abrupt system response. Therefore, managing for resilience enhances the likelihood of sustainable generation of ecosystem services benefiting humans in changing environments where the future is unpredictable and changes are likely. [20] [21] [22]
Improvement of resilience	Improvement of resilience involves increasing the ability of a system to withstand shocks and surprises and to revitalize itself if damaged. An integrated adaptive ecosystem management approach that increase ecosystem stability can improve the resilience of the environment and reduce vulnerability to improve the well-being of societies and ecosystems dependent on natural resources. Flexible sustainable decision-making processes that can accept new information and can be modified on the basis of this information are also important elements in building and/or improving resilience.

Table 10: Definition of keywords

In the following an overview on possible adaptation measures is given. The adaptation measures are classified in five different categories following the UNECE[23] and EEA[24]: preparation measures, ecosystem-based measures, behavioural/managerial measures, technological measures and policy approaches.

Preparation measures aim to support planning processes. This includes monitoring, evaluations of changes, identification of risk areas, elaboration of warning systems and emergency plans and the support of further research where needed.

Ecosystem-based measures aim to reduce negative effects of a changing climate by enhancing the capacity of the ecosystem to adapt to different impacts. These measures help to conserve or restore ecosystems. Healthy ecosystems can thus contribute to increase resilience for slow changes like increasing summer temperatures as well as for sudden impacts like floods.

Behavioural and managerial measures aim to raise awareness for possible future conditions and support sustainable management with a focus on the efficient use of water and conservation of good water quality. This includes inter alia the elaboration of risk management plans for water scarcity and the propagation of best practice, whereby the exchange of knowledge plays an important role.

Technological measures help to implement individual projects. The focus is on infrastructure, which has to be built or improved like dams, reservoirs, fish ladders or for water networks.

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[20] Resiliance Alliance (2012): research on resilience in social-ecological systems - a basis for sustainability. www.resalliance.org [Accessed 02.07.2012]

[21] Rockström, J. (2003): Resilience building and water demand management for drought mitigation. Physics and Chemistry of the Earth, 28, 869-877.

[22] Tompkins, E.L., Adger, W.N. (2003): Building resilience to climate change through adaptive management of natural resources. Tyndall Centre for Climate Change Research, Working Paper 27.

[23] UNECE (2009): Guidance on water and adaptation to climate change. United Nations Publication, Geneva.

[24] EEA (2010): The European Environment. State and Outlook 2010. Adapting to climate change - SOER 2010 thematic assessment. DOI: 10.2800/58998.

Policy approaches aim to support national, international and basin-wide coordination of activities. Common transnational threshold values, limits, restrictions, expansions (e.g. for protection areas or nature reserves), etc. should be considered.

Table 11 provides examples for possible adaptation measures which are valid for almost all impact fields. More detailed information on these and examples for other adaptation measures can be obtained from the "Danube Study", p. 39-45, tab. 2.

Examples for general adaptation measures
Preparation measures
Further, intensified monitoring activities to follow and assess climate change and climate change impacts
Homogenous data production, digital mapping and a centralized database for data exchange and comparability among regions and countries
Identification of potential risk areas and hot spots
Implementation of forecasting and warning services, e.g. of extreme events like floods and droughts
Development of action plans or integration of specific issues in ongoing planning activities, e.g. to deal with water scarcity and flood situations
Further research to close knowledge gaps, to determine vulnerability, to reduce uncertainty
Ecosystem-based measures
Taking environmental implications and the conservation of biodiversity into consideration in all other measures
Sustainable management of land use practices for improving the resilience and for enhancing the capacity to adopt to climate change impacts
Implementation of green infrastructure to connect bio-geographic regions and habitats
Protection, restoration and expansion of water conservation and retention areas
Rehabilitation of polluted water bodies
Behavioural and managerial measures
Support education, capacity building, awareness raising, information exchange and knowledge transfer
Establishment and support of an integrated risk management
Support of a water saving behaviour
Propagation of best practice examples
Application of sustainable methods, e.g. good agricultural practice
Technological measures
Adjustment of (existing) infrastructure, e.g. construction and modification of dams and reservoirs for hydropower generation, agriculture, drinking water supply, tourism, fish-farming, irrigation and navigation
Development and application of water-efficient technologies
Efficient waste- and sewage-water treatment and water recycling

Policy approaches
Support of an institutional framework to coordinate activities
Harmonization of international, basin-wide legal limits and threshold values
Implementation of restrictions, e.g. of development in flood risk areas
Expansion of protection areas, e.g. for drinking water resources
Adaptation of policies to changing conditions

Table 11: Examples for general adaptation measures

For each impact field future projections and possible adaptation measures classified into the five adaptation categories are described in detail in Chapter 5 of the "Danube Study – Climate Change Adaptation". It is recommended to use the different tables from Chapter 5 as an inspiring list of possible adaptation measures for specific impact fields when discussing and agreeing on measures to be taken in the frame of planning processes (references in Table 12).

Impact field	Table No.	Page
Water availability	Tab. 3	p. 50- 51
Groundwater quality and quantity	Tab. 4	p. 54- 56
Ice/Snow/Permafrost	Tab. 5	p. 60- 61
Droughts, Low flow, Water scarcity	Tab. 6	p. 65- 70
Floods	Tab. 7	p. 74- 82
Water temperature	Tab. 8	p. 85- 86
Water quality	Tab. 9	p. 89- 93
Water Supply/Water Demand	Tab. 10	p. 97-102
Agriculture	Tab. 11	p. 105-112
Irrigation	Tab. 12	p. 114-116
Forestry	Tab. 13	p. 119-122
Land Use	Tab. 14	p. 124-125
Soils/Erosion	Tab. 15	p. 128-129
Biodiversity/Ecosystems	Tab. 16	p. 132-136
Limnology	Tab. 17	p.139
Coastal Zones	Tab. 18	p. 141-142
Water related energy production	Tab. 19	p. 145-149
Navigation	Tab. 20	p. 152-154
Health	Tab. 21	p. 157-159
Tourism	Tab. 22	p. 163-164

Table 12: Link to tables of possible adaptation measures described in chapter 5 of the "Danube Study"

A changing climate affects all water-related sectors in different ways, both spatially and temporally. Therefore, disputes over planning and utilisation of suitable adaptation measures might increase. Additionally adaptation measures in one sector may have retroactive, positive or negative, effects on one or more other sectors. To prevent possible conflicts on the one hand and to foster common goals on the other hand, cross-sectoral, interdisciplinary and integral approaches are necessary. Integral approaches also aim to enhance synergy effects which should be sought. An example for a synergy effect is to increase water retention areas. This can lead on the one hand to a higher groundwater recharge and on the other hand to a reduction of flood peaks next to positive effects for biodiversity.

SECTION III - Guiding principles, integration and next steps

This section provides guidance on the integration of climate change adaptation in ICPDR planning processes for the Danube River Basin. A set of guiding principles, inter alia specifically targeted towards making the WFD and EFD operational towards adaptation activities for water-related issues and sectors, is followed by an indication of the required approaches and steps for the next planning phase. Adaptation to climate change as a cross-cutting issue requires the involvement of a range of relevant ICPDR Expert and Task Groups, whereas the Strategy provides orientation on how to utilize this expertise in place for adaptation.

As the next steps, it will be required to fill the Strategy with life by mainstreaming the suggested actions and integrating them in the planning activities towards the 2nd DRBM Plan and the 1st DFRM Plan. Beside the improvement of the knowledge base, it is suggested to check in 2018 whether there is a need to revise and update the Strategy, in line with the 6-years adaptive management cycles according to the WFD and EFD.

7 Guiding principles on adaptation and integration in ICPDR activities

7.1 Guiding principles on adaptation to climate change

This chapter gives an overview on guiding principles providing support for the integration of adaptation to climate change in river basin management, including flood and drought risk management (see Table 13 taken from the CIS Guidance Document No. 24[25]). The principles should be generally applicable and assist relevant experts active in the frame of the ICPDR during the next steps in the implementation process of the WFD and EFD in the Danube River Basin.

The guiding principles are in particular relevant for the planning process towards the 2nd DRBM Plan and the 1st DFRM Plan to be elaborated by 2015. However, they are also applicable for subsequent steps of WFD and EFD implementation on both, the national and international level.

The guiding principles are structured according to the following five main fields of actions, allowing orientation for relevant experts dealing with specific issues in the frame of river basin management:

I. Climate modelling, projections, scenarios, potential impacts and uncertainty

II. How to build adaptive capacity for management under climate change?

III. Water Framework Directive (WFD) and adaptation

IV. Flood risk management and adaptation

V. Drought management, water scarcity and adaptation

[25] European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.

Further detailed descriptions, suggested actions and practical examples for each of the guiding principles as summarised in Table 13 can be obtained from the CIS Guidance Document No. 24. The guiding principles on adaptation to climate change for flood risk management have already been addressed in the ICPDR concept paper in support of the implementation of the Directive 2007/60/EC in the Danube River Basin (IC-160 Coordination aspects of EFD implementation in the Danube River Basin).

Additional inspiring information is referenced in the Annex of the Strategy, providing an overview on case studies and good practice examples.

Issue	Guiding principles
I. Climate modelling, projections, scenarios, potential impacts and uncertainty	
Models, projections and scenarios	1. Climate projections and scenarios should be used for improving river basin management planning. 2. It is crucial to have a clear understanding of the assumptions made and the uncertainties related to these assumptions. 3. The best climate change model or scenario for a certain region or river basin should be decided on a case-by-case basis, because there is no "one-size-fits-all" model or scenario for Europe.
Managing the water environment based on uncertainty of projections and scenarios	4. Despite uncertainty in models, 'doing nothing' is not an option. For the next river basin management cycle, accept uncertainty where it is rational to do so and take first actions for adaptation to climate change. 5. Take best available scientific information into account. 6. Use a range of climate projections or scenarios in the analyses for river basin management planning in order to accept and work within the context of an uncertain future. 7. Prefer adaptation options which are robust against a range of future changes or postpone commitment to a particular projection of the future by building flexibility into your system.
II. How to build adaptive capacity for management under climate change?	
Using ongoing research and adaptation activities to increase knowledge at river basin scale	1. Link river basin management adaptation activities to national and regional climate change adaptation strategies and activities. 2. Check existing relevant science and research information on climate change modelling and impacts in the river basin. 3. Make use of good-practice examples coming, e.g. from existing research and implementation experience regarding adaptation strategies and measures. 4. Look beyond the borders of your river.
Data collection and building of partnerships	5. Evaluate coverage of data (e.g. meteorological, hydrological, water quality, soil moisture data, stake, damage cost data, etc). 6. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders. 7. Ensure communication and coordination on climate change adaptation issues between different levels of management within an RBD. 8. Work in cross-sectoral partnerships and across administrations. Ensure that climate change aspects are discussed between the relevant public administrations, in stakeholder meetings and discuss how relevant water-related sectors can contribute to adaptation. 9. Make sure to receive information related to the influence of climate change on

Issue	Guiding principles
	other sectors which are directly related to water management (e.g. agriculture-water demands, water needs for energy production, etc). 10. Integrate cross-sectoral delivery of adaptation measures and coordinate activities with land use planning.
Broadening the audience and increasing its capacities - Awareness-raising, education and training	11. Include the issue of climate change impacts in the river basin in your RBD awareness-raising activities as part of the WFD public participation process. 12. Establish staff training and capacity building programmes on climate change issues, e.g. to introduce staff to climate change modelling, scenarios and projections.
Looking beyond the borders	13. Develop joint or coordinated adaptation strategies in transboundary RBDs.
III. Water Framework Directive (WFD) and adaptation	
Assessing pressures and impacts on water bodies	1. Assess, over a range of timescales, direct influences of climate change and indirect influences where pressures are created due to human activities adapting to climate change.
Monitoring and status assessment	2. Maintain both surface and groundwater surveillance monitoring sites for long time series. Set up an investigative monitoring programme for climate change and for monitoring climate change “hot spots”, and try to combine them as much as possible with the results from the operational monitoring programme. 3. Include reference sites in long term monitoring programmes to understand the extent and causes of natural variability and impact of climate change.
Objective setting	4. Avoid using climate change as a general justification for relaxing objectives, but follow the steps and conditions set out in the WFD.
Economic analysis of water use	5. Consider climate change when taking account of long term forecasts of supply and demand and favour options that are robust to the uncertainty in climate projections.
How to do a climate check of the Programme of Measures?	6. Take account of likely or possible future changes in climate when planning measures today, especially when these measures have a long lifetime and are cost-intensive, and assess whether these measures are still effective under the likely or possible future climate changes. 7. Favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions. Design measures on the basis of the pressures assessment carried out previously including climate projections. 8. Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including GHG emissions.
What to do if other responses to climate change are impacting on the WFD objective of good status?	9. Avoid measures that are counterproductive for the water environment or that decrease the resilience of water ecosystems. 10. Apply WFD Article 4.7 to adaptation measures that are modifying the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) and deteriorate water status. 11. Take all practicable steps to mitigate adverse effects of counterproductive measures.
IV. Flood risk management and adaptation	
Overall guiding principle on flood risk	1. Start adapting flood risk management to potential climate change as soon as possible, when information is robust enough, since full certainty will never be

Issue	Guiding principles
management and adaptation	the case. Follow the guiding principles set out for the WFD.
Preliminary flood risk assessment	2. Understand and anticipate as far as possible climate change impact on flood patterns. 3. Use best available information and data. 4. Homogenize time series, and remove bias as far as possible. 5. Understand and anticipate as far as possible increased exposure, vulnerability and flood risk due to climate change, for establishing areas of potential significant flood risk
Flood Hazard and Risk Maps	6. When identifying the different flood scenarios, incorporate information on climate change 7. Present uncertainties surrounding climate change in maps transparently. 8. Use the 6-year review of flood maps to incorporate climate change information
Flood Risk Management Objectives	9. Incorporate climate change in setting flood risk management objectives 10. Ensure coordination at catchment level, also respecting the Directive's coordination requirements at RBD/unit of management level
Awareness raising, early warning, preparedness	11. Include climate change scenarios in ongoing initiatives and in the planning processes.
Measures	12. Perform a climate check of flood risk measures 13. Favour options that are robust to the uncertainty in climate projections a. Focus on pollution risk in flood prone zones b. Focus on non-structural measures when possible c. Focus on “no-regret" and "win-win" measures d. Focus on a mix of measures 14. Favour prevention through the catchment approach 15. Take account of a long term perspective in defining flood risk measures (e.g. with respect to land use, structural measures efficiency, protection of buildings, critical infrastructure, etc). e. Include long-term climate change scenarios in land-use planning f. Develop robust cost-benefit methods which enable taking into account longer term costs and benefits in view of climate change. g. Use economic incentives to influence land use [Link insurance] 16. Assess other climate change adaptation (and even mitigation) measures by their impact on flood risk: h. Hydropower and flow regulation i. Link with water scarcity
Links to WFD	17. Pay special attention to the requirements of WFD Article 4.7 when developing flood protection measures 18. Determine on the basis of robust scientific evidence and on a case-by-case basis whether an extreme flood allows for the application of WFD Article 4.6. 19. Pay special attention to the vulnerability of protected areas in view of changed flood patterns

Issue	Guiding principles
V. Drought management, water scarcity and adaptation	
Overall guiding principle on drought management, water scarcity and adaptation	1. Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in areas of water scarcity and to reduce the impacts of droughts.
River basin management plans as a tool for addressing water scarcity and droughts	2. Make full use of the Water Framework Directive environmental objectives, e.g. the requirement to achieve good groundwater quantitative status helps to ensure a robust water system, which is more resilient to climate change impacts. 3. Determine, on the basis of robust scientific evidence and on a case-by-case basis, whether a prolonged drought allows for the application of WFD Article 4.6, and take into account climate change predictions in this case-by-case approach. 4. Pay special attention to the requirements of WFD Article 4.7 when developing measures to tackle water scarcity under a changing climate and which may cause deterioration of water status.
Monitoring and Detecting Climate Change Effects	5. Diagnose the causes that have led to water scarcity in the past and/or may lead to it in the future. 6. Monitor water demand closely and create forecasts based on improved knowledge of demands and trends. 7. Collect as much high quality information as possible to anticipate changes in water supply reliability which may be imposed by climate change, in order to detect water scarcity early. 8. Distinguish climate change signals from natural variability and other human impacts with sufficiently long monitoring time series.
Adaptation measures related to water scarcity & droughts	9. Take additional efforts to prevent water scarcity and be better prepared to tackle the impacts of droughts. 10. Incorporate climate change adaptation in water management by continuing to focus on sustainability (balance between water availability and demand). 11. Follow an integrated approach based on a combination of measures (compared to alternatives based on water supply or economic instruments only). 12. Build adaptive capacity through robust water resources systems. 13. Engage stakeholders to produce decisive measures to tackle water scarcity. 14. Assess other climate change adaptation and mitigation measures by their impact on water scarcity and drought risks.

Table 13: Guiding principles for adaptation to climate change from CIS Guidance Document No. 24[26]

7.2 Integration in ICPDR activities

7.2.1 General considerations

Climate change is a cross-cutting issue, causing impacts on different sectors on a transboundary scale. The quality of water and its availability are very much in the heart of the expected changes and therefore requiring coordinated action in an integrative way. Due to the transboundary character of water and its relevance for various issues and water-related sectors (e.g. its role for biodiversity and

[26] European Communities (2009): Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 24. River Basin Management in a Changing Climate. Technical Report, Nr. 40.

the ecosystem, energy, transport, agriculture, floods and droughts, etc.), integrated river basin management is key for ICPDR´s approach to climate adaptation.

National experts covering a wide range of issues are cooperating in different ICPDR Expert and Task Groups on the coordinated implementation of the WFD and EFD. Taking advantage of this broad range of expertise is not only adequate but also crucial in order to address climate change accordingly by integrating adaptation activities in the ongoing and future planning process of the ICPDR.

Building on this basic rationale, work on climate change adaptation will be anchored in existing ICPDR structures and planning instruments as well as the corresponding national institutions and structures, allowing to deal with the significant complexity of the issue.

All relevant ICPDR Expert Groups and Task Groups are therefore mandated to fully integrate adaptation to climate change in the planning process for the implementation of the WFD and EFD in the Danube River Basin, specifically for the elaboration of next DRBM Plan and DFRM Plan.

7.2.2 Step-wise approach

The step-wise and cyclic approach of the river basin management planning process, for both the WFD and EFD, makes it well suited to adaptively manage climate change impacts. On the basis of the current knowledge it is unlikely that the additional effects of a climate change signal can be adequately distinguished from other human pressures and natural variability within the next WFD and EFD planning cycle. It is more likely that indirect pressures arising from human response to climate change will have a greater impact (such as elevated water abstractions for irrigated agriculture, or new flood defence infrastructure)[27]. It is therefore essential to step-wise adjust adaptation actions hand in hand with subsequent WFD and EFD planning cycles, building on increased experience and knowledge gained while taking into consideration climate change scenarios and expected water-related impacts (see Figure 11).

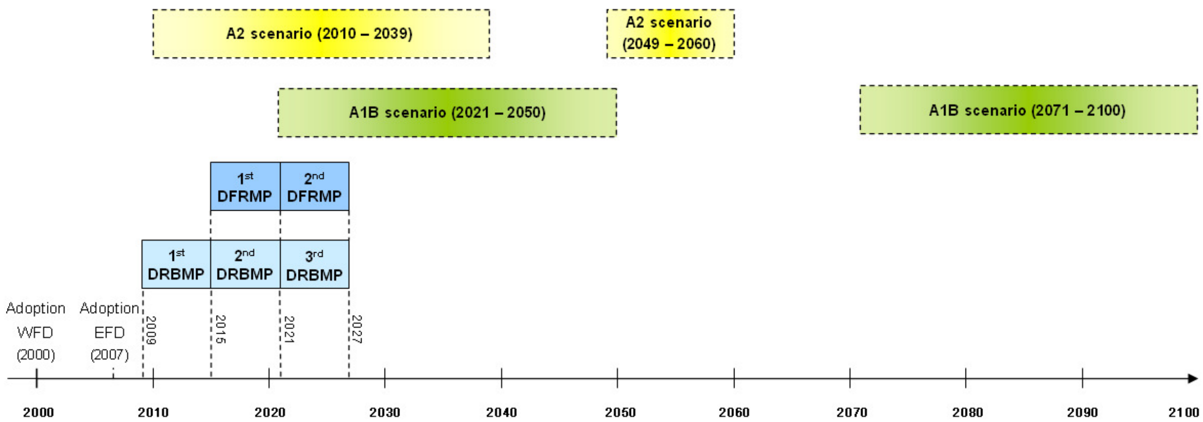

Figure 11: Overview timeframe WFD & EFD planning cycles in contrast to different climate change scenarios[28]

However, some of the implementation steps are considered more critically than others in our ability to prepare for climate change, especially in the short term. Essential components for planning for climate change are judged to be:

- an ability to identify change as it happens through monitoring;
- ensuring that the likely scale of impacts of climate change on existing and projected future anthropogenic pressures and risks is understood, and

[27] See CIS Guidance Document No. 24

[28] according to IPCC SRES scenarios and time periods described in chapter 3 and illustrated in Figures 4 to 7

- developing and prioritising multiple-benefit catchment based solutions which restore or maintain the natural characteristics of catchments to build resilience to a range of possible climate futures. In this context, measures should be examined to ensure that they will not fail under future climatic conditions.

These components should be the focus when considering how to deal with climate change. As such the pillars of the approach to adaptation in the frame of the 2nd DRBM Plan and the 1st DFRM Plan should be

1. effective long term monitoring (to enable climate change signals to be identified and reacted to in due course),
2. the assessment of the likely additional impact of climate change on existing and future anthropogenic pressures and risks, and
3. the incorporation of this information into the design of measures (particularly for proposed measures with a long term design life).

Thus, it should be clearly demonstrated how climate change projections have been considered in the assessment of pressures, impacts and risks, in the monitoring programmes, and in the choice of measures.

7.2.3 How to integrate adaptation in ICPDR planning processes?

A range of different actions is required to adequately integrate adaptation in the ICPDR planning process for WFD and EFD implementation. These include overarching activities, like the development of this Strategy or the future task of making use of improved climate modelling and building adaptive capacity for management under climate change (see fields of action I & II of Table 13), as well as activities which have to be directly incorporated in the planning process, in particular addressing monitoring and data exchange, assessment of pressures, impacts and risks as well as in the decision on measures (see fields of action III to V of Table 13).

It is therefore suggested to address adaptation to climate change twofold.

Regarding the overarching activities, the main actions and steps taken will be included in the next DRBM Plan and DFRM Plan in separate chapters on climate change and adaptation, since these are activities of a more general nature with relevance for the overall adaptation process for the Danube River Basin.

Regarding the second issue, adaptation will be directly addressed in the relevant chapters of WFD and EFD reports, in particular the 2nd DRBM Plan and the 1st DFRM Plan (e.g. how the monitoring system was adapted to enable tracking climate change signals, how climate change has been taken into account in the required assessments and the decision on measures). The following main steps can be indicated, providing support for relevant experts in the accomplishment of this task:

1. Get familiar with the climate change scenarios and expected water related impacts for the Danube River Basin (see Chapter 3 and Chapter 4 for an overview on the results of surveyed studies and more detailed information in the 'Danube Study – Climate Change Adaptation')
    a. Get an overall overview on the expected changes
    b. Pay special attention to the different impact fields within your field of action and expertise
    c. Pay attention to the issue of uncertainty
2. Take into account the guiding principles on adaptation to climate change (Chapter 7.1), providing specific guidance on different steps to be taken in adaptation for different issues (i.e. fields of action III to V on WFD, EFD, water scarcity and drought management)
3. Incorporate this knowledge in your planning process and make use of additional supportive information, i.e. on vulnerability and possible adaptation measures (Chapter 5 and Chapter 6)

4. Make use of case studies and good practice examples (Annex).

7.2.4 Integration between different levels of management

In the frame of the ICPDR, the trans-boundary aspects for the implementation of the WFD and EFD are coordinated on the basin-wide level (level A). Further detailed planning takes place on sub-basin and/or national level (level B) as well as on sub-unit level (catchments within national territories - level C). In the same way as for river basin and flood risk management, adaptation to climate change also requires communication and coordination between different levels of management within the Danube River Basin (see Chapter 2.2 on national and international adaptation activities).

In order to ensure coherence it is therefore crucial that awareness on ongoing adaptation processes is created and exchange is taking place between experts working on adaptation on different levels, in particular between level A and level B. This will be guaranteed via the involvement of national experts in the international working groups of the ICPDR, respectively via existing coordination approaches between the basin-wide and the sub-basin level within the Danube River Basin (Sava, Tisza, Danube Delta, Prut).

7.2.5 Integration between different sectors, synergies and prevention of potential conflicts

The ICPDR is following an approach with strong involvement of representatives from different sectors and interest groups in WFD and EFD planning processes (in particular observer organisations). This is crucial to ensure the required exchange and input, expected to lead towards better results in river basin and flood risk management. Exchange with and input from those groups will be maintained also with regard to climate change adaptation issues. In addition, the specific consultation processes as required by the WFD (Art. 14) and EFD (Art. 9 & 10) should be used to bring in sector-specific knowledge and data from key stakeholders.

Apart from the involvement of observer organisations, further targeted exchange on climate change adaptation with specific experts and interest groups outside existing ICPDR structures will be undertaken (e.g. by participation in respective meetings or the organisation of specific workshops on adaptation).

Finally, synergies but also potential conflicts need to be addressed at an early stage in the planning process and different stakeholders and interest groups need to be involved.

For example, the development of green infrastructure like the extension of natural areas and the re-connection of wetlands and floodplains leads to protect and maintain the natural ecosystem on one hand, on the other hand it can also help in the reduction of flood peaks. Further positive synergies which can be achieved by such adaptation measures can include the improved linkage between surface- and groundwater, leading to increased robustness with regard to potential periods of water scarcity and droughts.

On the other hand, structural adaptation measures for the improvement of navigation or for balancing water availability and water demand, in order to handle expected increasing water scarcity situations in the future, might lead towards potential conflicts with regard to the achievement of biodiversity objectives.

8 Next steps

8.1 Implementation steps WFD and EFD

The ICPDR Strategy on Adaptation to Climate Change will be fully taken into account during the next steps of the implementation of the WFD and EFD in the Danube River Basin. The next steps as indicated in Table 14 on implementation, following the indicated deadlines, are crucial to be considered for the integration of adaptation to climate change.

Deadline	Implementation step related to	
	EU Water Framework Directive	EU Floods Directive
22.12.2013	Update Danube Basin Analysis Report (agreed to be accomplished by first half of 2014)	Danube flood hazard and flood risk maps
22.12.2014	Draft 2nd Danube River Basin Management Plan available for public consultation	Draft 1st Danube Flood Risk Management Plan available for public consultation
22.12.2015	Final 2nd Danube River Basin Management Plan	Final 1st Danube Flood Risk Management Plan

Table 14: Overview next steps WFD and EFD implementation

8.2 Closing of knowledge gaps and identification of further research requirements

The 'Danube Study – Adaptation to Climate Change' identified besides commonalities in the impact studies also knowledge gaps and requirements for further research. Prerequisite for achieving progress in this regard are professionals who are able to apply the required activities (institutional adaptation), including the establishment and maintenance of databases, measurement networks, simulation models, analysis-software, laboratories, knowledge management systems or adjusted processes in the concerned institutions etc.

To improve the understanding of ongoing changes and their impacts better observational data and data access are necessary. Quality assurance and the homogenization of data sets help to improve model projections and are a prerequisite for adaptive management required under conditions of climate change within transboundary regions or catchments. In particular changes in water availability as well as changes in water demand in the Danube basin are of high interest on a monthly or higher temporal resolution scale.

There is a need to compare climate impacts across sectors and to systematically assess climate risks preferably based on a commonly agreed methodology and database. A basin-wide assessment could guide the selection of regional hot-spots for detailed impact studies. An interdisciplinary research team can acquire a multi-sector impact aggregation and a damage and risk assessment for short-term, medium-term or long-term applications.

It has to be clarified what the synergies and conflicts between climate change and land use planning are. Feedbacks between land use and climate change (including vegetation change and anthropogenic activity such as irrigation and reservoir construction) should be analysed more extensively, e.g. by coupled climate and land-use modelling. Furthermore, an evaluation of water-related consequences of different climate policies and development pathways is also of importance for a common adaptation strategy. Besides climate change impacts also socio-economic and demographic aspects are crucial for future adaptation measures.

A basin-wide approach which covers all relevant hydrological parameters is valuable to determine the impacts and consequences of climate change in the Danube River Basin. Particularly the Middle and Lower Danube River Basin might benefit from this approach due to relatively sparse information on climate change impacts in these regions. Due to the expected increasing water scarcity and drought situations in future summer periods in the south-eastern regions a basin-wide approach can give advice for the solution of transboundary environmental crisis and suitable adaptation measures. The assessment of water needs for the main utilities under several future circumstances, e.g. under severe drought and water shortage conditions can be projected. Upstream-downstream dependencies, taking into consideration also socio-economic and demographic changes, should be clearly presented.

Furthermore, model projections for the whole Danube basin with better land-surface properties and interactions as a large-scale climate model can provide suitable information on the catchment scale – the most important scale for water management.

8.3 Revision and update

In line with the step-wise and cyclic approach for the implementation of the WFD and EFD, it is proposed to check the need to update and revise the ICPDR Strategy on Adaptation to Climate Change. This should take place within an appropriate timeframe, allowing to

- Take into account updated information regarding the knowledge base on climate change and adaptation, in particular on climate change scenarios and water-related impacts in the Danube River Basin;
- Take the updated and revised Strategy into account for the planning process of the 3rd DRBM Plan and the 2nd DFRM Plan, due by 2021.

Based on these considerations, it is proposed to check the need for an update of the ICPDR Strategy on Adaptation to Climate Change in 2018 linking it with the 6-years planning cycles according to the WFD and EFD.

Annex – List of Case Studies and Good Practice Examples

The list below is an indicative list of case studies and good practice examples. For further information please also consult the Appendix of the 'Danube Study – Climate Change Adaptation'[29], available on the ICPDR website following the link: http://www.icpdr.org/main/activities-projects/climate-adaptation

Vulnerability and adaptation:

- **ADWICE** - Adapting Drinking Water resources to the Impacts of Climate change in Europe (ongoing). http://adwice.biois.com/
- **ATEAM** - Advanced Terrestrial Ecosystem Analysis and Modelling. Aim to assess the vulnerability of human sectors relying on ecosystem services with respect to global change. www.pik-potsdam.de/ateam
- **ClimWatAdapt** - Climate Adaptation – modelling water scenarios and sectoral impacts. The project results represent a series of tools which shall help improve the quality of adaptation measures, the knowledge base, and facilitate the exchange of adaptation best practice between countries and regions. www.climwatadapt.eu
- **EEA-EIONET** - European Topic Centre on Inland, Coastal and Marine waters. Report on good practice measures for climate change adaptation in river basin management plans, 2009. Available on http://icm.eionet.europa.eu/ETC_Reports/
- **MOTIVE** - Models for Adaptive Forest Management. The project investigates adaptive management strategies that address climate and land use change. http://motive-project.net
- **UNECE** - Transboundary pilot projects on climate change adaptation: http://www1.unece.org/ehlm/platform/display/ClimateChange/Welcome
  - UNECE Guidance on Water and Adaptation to Climate Change (2009)
  - UNECE Guidance on Water Supply and Sanitation in Extreme Weather Events (2011)
  - Transboundary Flood Risk Management - Experience from the UNECE region (2009)

Information systems:

- **BISE** - Biodiversity Information System for Europe. Facts and figures on biodiversity and ecosystem services, developed to strengthen the knowledge base and support decision-making on biodiversity. http://biodiversity.europa.eu
- **CLIMATE-ADAPT** - The European Climate Adaptation Platform aims to support Europe in adapting to climate change. www.climate-adapt.eea.europa.eu
- **ESPON** - European Observation Network for Territorial Development and Cohesion. Support policy development by providing comparable information, evidence, analyses and scenarios on territorial dynamics and revealing territorial capital and potentials for development of regions and larger territories. www.espon.eu

[29] Prasch, M., Koch, F., Weidinger, R., Mauser, W. (2012): Danube Study - Climate Change Adaptation. Ludwig-Maximilians-University Munich, Department of Geography. Final Report (available on icpdr-website).

- **WISE** - Water Information System for Europe. Water related information ranging from inland waters to marine. http://water.europa.eu/

Regional studies:

- **AdaptAlp** – Adaptation to climate change in the Alpine space. http://www.adaptalp.org/
- **ADAM** – Adaptation and mitigation strategies. The Tisza River Basin: Adaptation to climate change in floodplain management. http://www.tyndall.ac.uk/adamproject/tisza-river-basin
- **Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft**, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien, 2010, http://www.lebensministerium.at/publikationen/wasser/wasserwirtschaft_wasserpolitik/anpassungsstrategien_an_den_klimawandel_fuer_oesterreichs_wasserwirtschaft.html
- **Climate proofing the Danube Delta through integrated land and water management** (ongoing).
- **KomPass** - Competence Centre for Climate Change and Adaptation. Germany. www.anpassung.net
- **KLIMZUG -** Climate change in regions. Germany. www.klimzug.de
- **klimazwei** - Minimize risks, use chances. Germany. Projects on climate protection, climate change and adaptation. Development of practice-oriented strategies. www.klimazwei.de
- **Klima|Wandel|Anpassung** – Adaptation to Climate Change. Austria. www.klimawandelanpassung.at