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COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)

Guidance document No. 24
RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE

EUROPEAN COMMISSION

environment

Status box 30 November 2009

The EU Water Directors endorsed this Guidance document during their meeting on 30 November 2009 in Sweden. This version will be subject to final editing and lay out improvements in December 2009. The edited version will be made available on Circa and on the EC water webpage in December.

A great deal of additional information on the European Union is available on the Internet.

It can be accessed through the Europa server (http://ec.europa.eu).

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1 Foreword

In the context of the WFD Common Implementation Strategy, an activity on Climate Change and Water was initiated in 2007 to produce guidance on how Member States should incorporate consideration of climate variability and change into the implementation of EU water policy. In 2008, the Water Directors discussed and agreed key policy messages on Climate Change and Water.[1] These focused on the following topics:

– EU water legislation and its ability to allow and support adaptation to climate change.

– The importance of integration with other policies.

– WFD and objective-setting under a changing climate.

– How adaptation is addressed in the 1st RBMPs.

– The role of adaptation in the 2nd and 3rd river basin management cycles.

This EU guidance builds upon these policy messages and is a mentioned as a priority action in the EC's White Paper on Adapting to Climate Change (2009).

It has been discussed with a wide range of stakeholders and experts in the framework of the Common Implementation Strategy, and it reflects the important role of water managers in adapting to climate change.

This guidance intends to give support to river basin managers in incorporating climate change in the next river basin management cycles. Further work may be needed and will be undertaken in the Common Implementation Strategy.

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1 http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/climate_adaptation&vm=detailed&sb=Title

2 Executive Summary

Introduction

1. Europe's fresh, transitional and marine waters have been affected by centuries of deliberate management as well as by the unintended consequences of changes in land-use, water abstraction and pollution. Without proactive measures, the continent's water bodies may be further modified by growing pressures from the direct and indirect effects of climate variability and change.

2. Climate change is projected to lead to major changes in yearly and seasonal precipitation and water flow, flooding and coastal erosion risks, water quality, and the distribution of species and ecosystems. Models indicate that at a general level the south of Europe will show a significant drying trend and the north of Europe one of wetting. At a regional scale, the patterns of potential changes can be rather diverse. These changes will most likely become significant in the second half of this century.

3. The European Commission White Paper *Adapting to climate change; Towards a European framework for action* (COM/2009/147) calls for a more strategic approach to climate change adaptation across different sectors and levels of governance. It calls for guidance to integrate climate change adaptation into implementation of the EU water policy. This is also recommended by the European Water Directors.

4. Several existing European Union (EU) policies address water management issues. The most important are the EU Water Framework Directive (WFD) and its daughter directives, the EU Floods Directive, and the EU Water Scarcity and Droughts Strategy. Collectively, these provide legal instruments for protecting and restoring the water environment, as well as steps that can be taken to reduce risks to human health, cultural heritage and economic activity.

5. Although climate change is not explicitly included in the text of the WFD, the step-wise and cyclical approach of the river basin management planning process makes it well suited to adaptively manage climate change impacts. This approach means that we can revisit plans to scale up or down our response to climate change in accordance to monitored data, and can avoid over-investment now. On the other hand, it is important that long term climate projections are built in to the design of measures (driven by current pressures) that have a long design life and high costs. As such, inclusion of climate change in assessment of pressures is important.

6. In addition the river basin management planning process is the best mechanism through which to balance available water resources and demands, thus avoiding long term water scarcity, and provides clear links to the management of flood risk in catchments, which is specifically addressed through requirements in the Floods Directive.

7. The purpose of this Guidance Document is to illustrate ways in which preparations can be made for climate change within the second and third River Basin Management Planning (RBMP) cycles, including provision for floods and droughts. As a minimum, this will require Member States to clearly demonstrate how climate change projections have been considered in the assessment of pressures and impacts, monitoring programmes and appraisal of measures.

8. This Guidance Document describes guiding principles for adaptation, and relates each to steps in RBMP. The principles are intentionally broad to be applicable across all Member States regardless of regional variations in potential impacts. Where feasible, entry points have been identified within existing processes and frameworks. Examples

are provided to show how the principles might be applied in practice. This guidance document is not focused around climate change mitigation measures, although some principles related to integration of different sectors are also applicable to specific mitigation measures such as measures related to renewable energy. Moreover, there is a potential for win-win solutions contributing both to mitigation and adaptation.

9. The Guidance is conveyed in five blocks that explain: (1) how to handle available scientific knowledge and uncertainties about climate change; (2) how to develop strategies that build adaptive capacity for managing climate risks; (3) how to integrate adaptive management within key steps of the RBMP of the WFD; and how to address the specific challenges of managing future (4) flood risk and (5) water scarcity.

10. This Guidance is endorsed by Water Directors. It is aimed at those with responsibility for river basin management, including flood and drought risk management, for delivery of the second and third RBMP cycles (from 2015 until 2027). This will require a combined approach that balances action on monitoring and understanding climate-driven impacts, with implementing no regret actions to improve resilience and ensuring that long life-time investments are climate resilient.

Handling scientific knowledge and uncertainties about climate change

11. Projections of future climate change are obtained from global climate models. These use mathematical equations to characterize fundamental processes involving the transfer of heat, mass, momentum and water vapour amongst major earth systems (such as the ocean, atmosphere, hydrosphere and cryosphere).

12. Depending on the assumed greenhouse gas emissions scenarios and approximations used to represent some natural processes (such as cloud formation), climate change projections can diverge significantly over the second half of the 21st century. However, over the next few decades, the outlook for temperature is largely independent of the emissions scenario because it will be dominated by natural variability and the response of the oceans to past emissions.

13. Over the longer term, major changes in annual water availability are expected across Europe. In general, water availability is projected to increase in northern regions, although summer river flows may decrease. Southern and south eastern parts of Europe, which already suffer water stress, could experience reductions in water resources due to increased frequency and intensity of droughts. On the other hand, increasing intensities of heavy rain events are projected to increase peak river flows across some parts of the continent. Several European research projects focus on better predicting these future trends.

14. Although there are regional variations, upward trends in surface air and water temperatures are projected for Europe. However, temporary cooling is still expected to occur in individual years and decades due to natural climate variability. Projections of changes in precipitation and flows at the river basin scale are less certain, due to large natural variability in these quantities, as well as the limitations of climate models, and assumptions used to downscale information between climate and hydrological models.

15. Potentially all elements included in the definition of WFD qualitative and quantitative status of water are sensitive to climate change. This includes: water availability (river flows and groundwater levels); water demand (especially peak demands during droughts); intensity and frequency of extreme events (floods and low flow episodes); water quality (including temperature, salinity, nutrient and contaminant concentrations.

sediments); and biodiversity of aquatic ecosystems. However, disentangling the effects of climate factors from other changes will continue to be difficult.

16. Given deep uncertainty about regional climate change projections and realised impacts on aquatic ecosystems, RBMP should incorporate management strategies that deliver benefits regardless of the climate outlook. Robust and adaptive RBM measures are low regret, or reversible, incorporate safety margins, employ 'soft' solutions, are flexible, and mindful of the actions being taken by others to either mitigate or adapt to climate change.

17. In practice this means embracing uncertainty by analysing the performance of river basin management plans against the projections of a wide range of climate model and emissions scenarios. Through sensitivity testing it should then be possible to establish which individual or combinations of measures are most effective at achieving water management objectives.

Developing strategies that build adaptive capacity for managing climate risks

18. According to the Intergovernmental Panel on Climate Change (IPCC), adaptive capacity may be defined as the *ability to cope, adapt or recover from the effects of a hazard* (in this case, climate change). Examples of steps that can be taken to build adaptive capacity include: increasing knowledge of potential climate risks for individual river basins; strengthening data collection and knowledge exchange amongst key stakeholders; cross-sectoral integration and partnership working; awareness raising education and training.

19. National and regional climate risk assessments can provide valuable contextual information for individual river basins. Information inventories and meta-analysis can also help pool evidence of observed or anticipated water sector impacts at basin scales. Furthermore, existing work may point to potential transboundary impacts and adaptation options, or good-practice case studies and implementation experience that can be shared amongst neighbours.

20. Reviews of existing knowledge may highlight information gaps that can only be filled by extending data collection and monitoring programmes. However, any consideration of data requirements should be anticipatory of changed patterns of climate pressures and receptor responses. Likewise, long-term monitoring will be needed to track emerging risks and to evaluate the effectiveness of any adaptation interventions.

21. Meaningful and early stakeholder engagement can improve the chance of acceptance of measures and hence the delivery of an integrated, cross-sectoral adaptation strategy. This will also help to minimize potential cross-sectoral conflicts whilst maximising possible synergies between adaptation plans. Therefore, effective lines of communication and coordinated action should be established at all levels of management within the River Basin District (RBD).

22. All water related sectors should be well-informed about the possible impacts of climate change. This might require further training and professional development in climate change science, or forums to enable knowledge transfer between organisations, and broadening of the audience through the public participation processes of the WFD and the Floods Directive.

23. Transboundary river basins pose especially complex challenges with regard to the building of adaptive capacity for climate change. Joint bodies such as international river basin commissions should oversee the development of coordinated adaptation strategies and put in place mechanisms for implementing and monitoring measures.

This may require more technical capacity and foresight needed to undertake such tasks.

Integrating adaptation within key steps of River Basin Management Planning

24. As noted before, the underpinning rationale and processes of the WFD are amenable to the delivery of adaptation. In particular, the integrated approaches to land, water and ecosystem management, combined with the cyclical review process, are all consistent with the ideals of adaptive management. Steps in the RBMP process provide a convenient structure for incorporating adaptation to climate change through: risk appraisal, monitoring and assessment, objective setting, economic analysis and Programmes of Measures (PoMs) to achieve environmental objectives.

25. The Guiding Principles summarised below are intended to help river basin managers to take well informed decisions that are proportionate and robust, given acknowledged uncertainties in regional climate change impacts. Where feasible, "no-regret", or "win-win" measures should be adopted as these yield beneficial outcomes regardless of the eventual outcomes of climate variability and change.

26. As a minimum Member States should clearly demonstrate in the second and third cycle RBMP how climate change projections have informed assessments of WFD pressures and impacts; how monitoring programmes are configured to detect climate change impacts; and how selected measures are as robust as possible to projected climate conditions.

27. Apart from exceptional circumstances, it is not expected that, within the timeframe of WFD implementation (i.e., up to 2027), and within the metrics used for status assessment, that a climate change signal will be statistically distinguishable from the effects of other human pressures at a level requiring reclassification of sites. It is more likely that indirect pressures arising from human responses to climate change – both adaptation and mitigation - will have a greater impact (such as elevated water abstractions for irrigated agriculture, new flood defence infrastructure or effects on water quality and quantity of intense production of energy crops).

28. The following sections provide additional commentary on key guiding principles included in the Guidance. These 11 key guiding principles are considered most useful for river basin managers who want to get acquainted with principles of adaptation in water management in a general way. For additional guiding principles, and for more detailed commentary, suggested actions, case studies and examples the reader is referred to the main body of the guidance.

29. <u>Principle 1: Assessing direct and indirect climate pressures</u>. Member States are required to carry out a review of the impact of human activities on the status of surface and ground waters (e.g., point and diffuse source pollution, abstraction). Potentially all such pressures will be sensitive to climate change, therefore, it is helpful to distinguish between primary and secondary pressures. The former describe direct links between climate driver(s) and natural system response(s) (e.g., increased metabolic rates due to higher water temperatures, more frequent flushing of sewer outflows). Secondary pressures arise from indirect links to climate change due to societal responses (e.g., increase storage to avert water scarcity). Risk assessments that are too narrowly focused on existing pressures within river basins may overlook important but physically remote, indirect or longer-term drivers of water body status.

30. <u>Principle 2: Detecting climate change signals</u>. Monitoring data will be needed to identify and react to climate change signals as they emerge, so it is important to assess how

best use can be made of available data from existing networks, and that sites with relevant long data records are sustained over coming years as part of wider surveillance efforts. Knowledge of when and where climate change might be first detected can help target investigative monitoring and reporting of effects in the most vulnerable water bodies (i.e., "hot spots"). Climate change indicators can be deployed that improve the chance of early detection, and hence the lead-time for invoking adaptive measures.

31. Principle 3: Monitoring change at reference sites. Human activities and climate changes at the river basin scale may have similar outcomes in the quality elements used for status assessment. Therefore, robust information on changes at reference sites – locations that by definition are subject to limited anthropogenic modification – is the primary means of isolating the two sets of impacts.

32. Principle 4: Setting objectives. Although the use of exemptions is an integral part of RBMP, applying exemptions without justification in line with the WFD cannot be seen as a general strategy for coping with the consequences of climate variability and change. Therefore, climate change should only be used as justification for exemptions where there is convincing evidence and certainty that climate projections will combine with a lack of proportionate and feasible measures to require lower than default objectives to be set.

33. Principle 5: Forecasting the economics of water supply and demand. Sequential steps in the economic analysis of the WFD should be followed, but with the integration of potential additional pressures, impacts and constraints due to climate change. The value of water could be affected as the balance between supply and demand is reconfigured. Therefore, economic analyses should identify the most cost-effective combinations of measures under a plausible range of climate change and water supply-demand scenarios.

34. Principle 6: Checking the effectiveness of measures. Due to the fact that substantial financial resources will be invested within coming river basin management cycles, and that many measures will have a long lifespan and/or preclude future adjustments, Member States/RBD authorities have to screen for potential effects by undertaking a "climate check" of the PoMs. This check should involve a sensitivity analysis of the proposed measure or group of measures to evaluate long-term effectiveness and cost-efficiency under changing conditions. If it is found that the measure(s) are potentially sensitive to the anticipated climate change, then the measure should be re-evaluated and adjusted accordingly. Preferred options will be able to cope with a range of climate conditions or are sufficiently flexible to be adapted to changing conditions. The methodology of the climate check should be fully transparent and documented so that the process can be replicated should new or improved evidence of future climate risks become available. Monitoring programmes should also be in place to verify or amend the findings of the climate check.

35. Principle 7: Favouring robust adaptation measures. Proactive adaptation measures may be required if climate change threatens to jeopardise the achievement of WFD objectives. In practice, other, non-climatic pressures are more likely to be of concern over the course of the second and third RBMP cycles. Therefore, the first priority should be to establish/safeguard monitoring programmes that will help benchmark and track long-term climate change impacts as they materialise. Indeed, monitoring and reporting are crucial elements of any adaptive management system. However, if investments are being planned for infrastructure with long life spans it is prudent to favour measures that are resilient to a wide range of plausible climate conditions. Ideally these measures should also work with natural processes and realise multiple

benefits (e.g., for flood risk management, drought management, nature conservation, navigation and recreation.

36. Principle 8: Maximise cross-sectoral benefits and minimise negative effects across sectors. Robust adaptation measures will also make provision for the actions being taken by others to either mitigate or adapt to climate change. For instance, policies intended to reduce greenhouse gas emissions could lead to hydropower development or biomass cultivation with potentially significant consequences for aquatic ecosystems. On the other hand measures taken to improve water status through waste water treatment or reuse, artificial recharge of aquifers, inter-basin transfers, and so forth, imply higher energy consumption and greenhouse gas emissions. The main body of the guidance offers criteria to help select adaptation measures that are effective and cost-efficient, yet minimise side-effects, promote equity, and are technically and socially feasible within the implementation time-scale. Land use planning is an important tool in preventing long term negative effects.

37. Principle 9: Apply WFD Article 4.7. In the event that no *significantly better environmental options* exist, and all practicable steps have been taken to minimise the adverse effect of the proposed measure, WFD Article 4.7 may be invoked. This provides the possibility of exemption from achieving good status when a physical alteration to a water body is deemed to offer benefits that outweigh the costs to the environment.

38. Principle 10: Flood risk management: Start adapting flood risk management to potential climate change as soon as possible, when information is robust enough since full certainty will never be the case. Follow the guiding principles set out for the WFD.

39. Principle 11: Drought management and water scarcity: Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in water scarce areas and to reduce the impacts of droughts.

Specific issues relating to flood risk

40. Future changes in the intensity and frequency of extreme precipitation events, combined with changing land use, are expected to cause an increase in flood risk across much of Europe. The Flood Directive shares many features of the WFD, such as the cyclical approach to risk assessment, preparation of management plans, and consultation process. However, what distinguishes the Flood Directive from the WFD is that the risk assessment places safety issues at the centre. Many of the above mentioned guiding principles are therefore directly applicable to flood management.

41. The Flood Directive further highlights the need for coordinated action on climate change throughout the RBD, particularly where there are transboundary or shared flood risk issues. Some information collected under the WFD is of relevance to flood management. The Preliminary Flood Risk Assessment also requires that past floods are taken into account, so efforts to homogenize and remove biases from river flow records will be helpful to trend detection more generally.

42. WFD and flood risk management objectives potentially overlap in several places with respect to climate change. For example, more frequent floods can have benefits for aquatic ecology, soil fertility, groundwater recharge and biodiversity. WFD Article 4.6 makes provision for temporary deterioration in the case of extreme floods, but should not be used by Member States as a means of avoiding obligations under the Directive. As noted above, WFD Article 4.7 refers to possible exemptions for new infrastructure projects.

Specific issues relating to water scarcity

43. Climate change is expected to aggravate the structural problems that already lead to water scarcity in some European countries. However, a distinction should be made between drought and water scarcity: – the former refers to a temporary deviation of the natural water cycle from the long-term average; the latter to a long-term, systemic imbalance between water supply and demand. Both supply and demand have the potential to affect the status of water bodies as the frequency, duration and intensity of droughts could change in the future.

44. River Basin Management Plans required by the WFD offer considerable potential for addressing the consequences of drought and water scarcity issues. The planning process provides scope for analysing pressures, setting objectives and establishing cost-effective counter measures. For example, achieving good groundwater quantitative status may require rebalancing of abstraction and recharge of groundwater. Measures to achieve these objectives may include economic instruments such as water pricing, and other incentives to use water resources more efficiently. As with the Floods Directive, WFD Articles 4.6 and 4.7 may also be invoked, but in this case, for respectively unforeseen prolonged droughts and new infrastructure designed to tackle water scarcity.

45. Given the high degree of uncertainty in climate change projections and the growing pressure on water resources, it is essential that hydrometric networks are in place to monitor droughts, and that the causes for water scarcity are thoroughly diagnosed, e.g. to monitor water demand and long-term trends in water supply.

46. A further priority is to intensify efforts to manage demand and thereby reduce pressure on water supply sources, especially in times of droughts. The greatest scope for action is in reducing irrigation demands which usually account for the largest fraction of total demand in water scarce regions. Other measures include reducing leakage in water distribution networks, wastewater recycling, and market-based instruments. Further robustness can be built into water resource systems by integrating multiple sources of supply and demand in conjunctive schemes, whilst the potential consequences for water ecosystems have to be considered thoroughly.

47. The above common concerns underline the need for close coordination and active participation of all interested parties in the river basin and flood risk management process, extending beyond the traditional remit of water managers and engineers, to spatial planners, insurance providers, private and public stakeholders.

3 INTRODUCTION

European freshwaters, transitional and marine waters are already being affected by many human activities, e.g. due to land-use, water abstraction and pollution with nutrients and hazardous substances. There are many indications that water resources, which are already under stress from human activities, are highly susceptible to climate change impacts and that climate change may hinder attempts to prevent deterioration and/or restore some water bodies to good status. Climate change is projected to lead to major changes in yearly and seasonal water availability across Europe in the long run, and an increase in extreme river flows is projected for large parts of Europe.

However, on the basis of current knowledge, it is unlikely that within the timeframe of the Water Framework Directive (WFD) implementation (i.e. up to 2027), the effects of a climate change signal will be adequately distinguishable from other human pressures and natural variability to the extent that extensive changes in status become necessary. Only in relatively few particularly sensitive cases, is it likely that climate change could impact status assessment in the relatively short term. It is more likely that first climate change related effects on water status are to be expected from adding to the burden of existing anthropogenic pressures on water bodies, such as increased water abstraction because of higher summer temperatures, or increasing diffuse pollution due to increasing rainfall intensities.

What is the purpose of this Guidance?

The present Guidance Document focuses on **how climate change could be integrated into the 2nd and 3rd river basin management (RBM) cycles of the WFD also broadening the scope to floods and droughts**. This EU Guidance was identified as a priority action by the White Paper of the European Commission on "Adapting to climate change: Towards a European framework for action".

Across Member States, consideration of climate change has been introduced to river basin management processes in a largely qualitative way, if at all, for the **1st RBM cycle for the WFD**. In some cases, adaptation has tended to be considered towards the end of the river basin management process. For the 1st cycle, the Policy Paper of the Water Directors placed particular emphasis on ensuring that the Programmes of Measures are sufficiently adaptive to future climate conditions (so-called climate-check of the Programme of Measures, based on available knowledge, data and common sense).

For the **2nd and 3rd RBM cycles for the WFD**, it is expected that climate change should be fully integrated into the process of river basin management. As such the pillars of the approach to adaptation through river basin management under the WFD 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 anthropogenic pressures, and 3) the incorporation of this information into the design of measures (particularly for proposed measures with a long term design life). Thus, it is expected that as a minimum, Member States should clearly demonstrate how climate change projections have been considered in the **pressures & impacts assessment**, in the **monitoring programmes**, and in the **choice of measures**.

Regarding the Floods Directive, climate change should be considered in the first flood risk planning cycle within the preliminary flood risk assessment and based on available information, as well as in subsequent cycles of planning, when carrying out the revision and updating of the preliminary flood risk assessment and the flood risk management plans.

To whom is this Guidance addressed?

This Guidance is aimed at those with responsibility for river basin management, including flood and drought risk management, in particular for delivery of the 2nd and 3rd river basin management cycles of the WFD (from 2015 until 2027).

What to find in this Guidance?

The main chapters of this document (chapters 5-9) follow a similar pattern in terms of the structure of the guidance provided:

Guiding principles

Guiding principles are introduced in text boxes in the beginning of each chapter or key subchapter. The principles are meant to be generally applicable and intentionally broad to be valid across all Member States. The text boxes are followed by more detailed text explaining the principles.

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Suggested actions

Following the explanatory texts of the guiding principles, text boxes introduce more concrete and practical actions to be taken in the coming years in order to apply the principles.

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Examples

The guiding principles and suggested actions are complemented by examples which intend to show how the principles and actions might be applied in practice. Some of the examples are generic or fictive and no specific source of reference for further information can be given.

The Guidance starts with an overview of the EU policy framework relevant to water issues and climate change as well as reference to relevant adaptation initiatives in the Member States (*chapter 4*).

Chapter 5 provides a concise introduction to the use of models, projections and scenarios as key tools and information sources for those with responsibilities in river basin management to determine the likely impacts of climate change in river basins. Guiding principles are proposed on how to handle uncertainty from models, projections and scenarios in river basin management decision-making.

Going beyond the handling of available scientific knowledge and related uncertainties, *chapter 6* provides guidance on setting up a strategy for building adaptive capacity for management under climate change, serving as a reminder of key aspects such as awareness-raising, stakeholder involvement, proper staff training and cooperation between different levels of authorities and sectors.

Chapter 7 puts forward guiding principles for adaptation to climate change in relation to the key steps in River Basin Management under the WFD (pressure and impact assessment; monitoring and status assessment; objective setting; economic analysis; measures for adaptation related to the WFD).

Chapters 8 and 9 provide specific guidance on flood risk management and drought management under climate change.

Which guiding principles are put forward in this Guidance?

The following table gives an overview of the overall guiding principles proposed in the different blocks of this Guidance Document.

Issue	Guiding principles
Climate modelling, projections, scenarios, potential impacts and uncertainty (chapter 5)	
Models, projections and scenarios (section 5.1)	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 (section 5.3)	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.
How to build adaptive capacity for management under climate change? (chapter 6)	
Using ongoing research and adaptation activities to increase knowledge at river basin scale (section 6.2.1)	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 (section 6.2.2)	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 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 (section 6.2.3)	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 (section 6.2.4)	13. Develop joint or coordinated adaptation strategies in transboundary RBDs.
Water Framework Directive (WFD) and adaptation (chapter 7)	
Assessing pressures and impacts on water bodies (section 7.3)	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 (section 7.4)	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 (section 7.5)	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 (section 7.6)	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? (section 7.7.2)	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? (section 7.7.3)	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.
Flood risk management and adaptation (chapter 8)	
Overall guiding principle on flood risk management and	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 the case. Follow the guiding

adaptation (section 8.1)	principles set out for the WFD.
Preliminary flood risk assessment (section 8.2)	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 (section 8.3)	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 (section 8.4.1)	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 (section 8.4.2)	11. Include climate change scenarios in ongoing initiatives and in planning processes.
Measures (section 8.4.3)	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 on their impact on flood risks: h. Hydropower and flow regulation i. Link with water scarcity
Links to WFD (section 8.4.4).	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
Drought management and water scarcity and adaptation (chapter 9)	
Overall guiding principle on drought management, water scarcity and adaptation (section 9.2)	1. Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in water scarce areas and to reduce the impacts of droughts.
River basin management plans as a tool for addressing water scarcity and droughts (section 9.2)	2. Make full use of the Water Framework Directive environmental objectives, e.g. by the requirement to achieve good groundwater quantitative status 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 (section 9.3)	5. Diagnose the causes that led to water scarcity in the past and/or may lead to it in the future. 6. Monitor water demand closely and forecast it, based on improved knowledge about demands and trends. 7. Collect as much high quality information as possible to anticipate changes to 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 (section 9.4)	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 the focus on sustainability (sustainable 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. Involve stakeholders for engagement to realise decisive measures to tackle water scarcity. 14. Assess other climate change adaptation and mitigation measures on their impact on water scarcity and drought risks.

4 WATER AND CLIMATE CHANGE – POLICY FRAMEWORK

Several existing EU policies and initiatives contribute to efforts for adaptation to climate change with regard to water issues. The most important ones are the EU Water Framework Directive (WFD) and its daughter directives, the EU Floods Directive, the Water Scarcity and Droughts EU Policy as well as the EC's White Paper on Adaptation (see following sections for details). These policies and initiatives refer to:

- Building resilience against the added risk of climate change by acting on existing anthropogenic risk,
- Using a cyclic management approach to include increasing knowledge over time on climate change impacts,
- Using the opportunity of implementation of existing initiatives to:
    - restore natural ecosystem function within catchments, in particular the ability of catchments to retain and slowly release water and to degrade pollutants,
    - reduce fragmentation and improve connectivity of habitats to allow species movements,
    - balance ecology and economic developments.

4.1 Introduction to WFD

The **Water Framework Directive** 2000/60/EC (WFD) establishes a legal framework to protect and restore the water environment across Europe by 2015 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.

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 chapter 7 of this Guidance).

In many cases, climate change impacts may put additional pressure on European water resources. From the Article 5 characterisation reports assessed for the Commission's WFD implementation report in 2007,[2] there were no indications that climate change pressures are significantly putting the achievement of good status at risk in the first RBM cycle. However, it is important that 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 WFD objectives and adaptation aims. **Thus the second river basin management plans due in 2015 should be designed to be robust to the impacts of climate change and climate variability.** This means that it needs to 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] COM(2007) 128 final, 'Towards sustainable water management in the European Union' and its Annex SEC(2007) 362

4.2 Introduction to Floods Directive

Besides the WFD, the **Floods Directive** 2007/60/EC also provides a framework for adaptation with regard to water issues. This Directive establishes a legal framework for the assessment and management of flood risks across Member States, aiming at reducing the adverse consequences of floods to the human health, the environment, cultural heritage and economic activity. The Directive requires Member States to produce the first flood risk management plans (FRMPs) in 2015 in those areas for which potential significant flood risk has been assessed. FRMPs 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 **preliminary flood risk assessment**, **flood hazard and risk maps** and **flood risk management plans**.

In contrast to the WFD, climate change is explicitly included in the Floods Directive, and Member States are clearly expected to take into account the likely impacts of climate change on the occurrence of floods.[3]

In addition, for the implementation of the Floods Directive, co-ordination with the implementation of the WFD is required by its article 9 from the second cycle of the WFD river basin management plans (RBMP) and onwards. There is an opportunity through alignment to deliver alternative more cost-effective and sustainable catchment based approaches that deliver multiple benefits for flood risk management, water scarcity and drought management and river basin management outcomes. The requirement to coordinate the two Directives therefore establishes an appropriate framework for implementation, so that differing and conflicting interests can be properly balanced and maximum synergies gained.

Chapter 8 of this Guidance focuses on how to address the potential changes in flood hazards due to climate change from the first cycle and how - in view of potential increased flood risk - to limit the vulnerability and potential adverse consequences.

4.3 Introduction to water scarcity and droughts policy

The European Commission adopted an official Communication regarding water scarcity and droughts on 18 July 2007 (EC 2007b), which aims to further develop adaptation measures to address expected increasing impacts of water scarcity and droughts in next decades.

The Communication presents a range of possible options for managing the problems of water resource scarcity and drought, and quotes a certain number of good practices existing in various countries thereby stressing that water saving should become the priority; furthermore, it recommends drafting Drought Management Plans, provides support to establish a European Strategy, proposes to establish a European Drought Observatory (under development by JRC) and introduces the possibility of using European funds for countries suffering prolonged droughts.

The Communication recommends that all possibilities to improve water efficiency must be explored, and that policymaking should be based on a clear water hierarchy, i.e. additional water supply infrastructures should be considered as an option when other options have been exhausted. The Council endorsed the Communication and considered it as a

[3] Article 4 (FD) states that the preliminary flood risk assessment shall be based on among other things "impact of climate change on the occurrence of floods" from the first cycle, and article 14.4(FD) makes the consideration of the "likely impact on climate change on the occurrence of floods shall be taken into account in the reviews [of the preliminary flood risk assessment and the flood risk management plans]".

fundamental and well-developed first set of policy options for future action, within the framework of EU water management principles, policies and objectives. In particular, the Council stressed that the WFD river basin management plans are the appropriate means to address water scarcity and droughts and that demand side measures should clearly be favoured over supply side measures to the extent possible.[4]

In this spirit, the Guidance at hand emphasises the importance of the common implementation of the WFD and its river basin management plans with the EU policy initiatives on scarcity and droughts. The EU Communication on water scarcity and drought therefore served as a building block for developing the guidance provided in chapter 9 of this document on drought management, water scarcity and adaptation. The follow-up report of the Communication on water scarcity and droughts (EC 2008) shows that, while progress has been made, a great deal still needs to be done in order to improve water demand management more widely across Europe and to avoid mismanagement of water resources, especially in water-scarce areas.

4.4 EC White Paper on Adaptation

The White Paper of the European Commission "Adapting to climate change: Towards a European framework for action" (COM/2009/147) was issued in April 2009 and sets out a framework to reduce the EU's vulnerability to the impact of climate change.

As efforts are underway to reduce greenhouse gas emissions in the EU, there is further need to take adaptation action in order to deal with the unavoidable climate change and subsequent risks. The White Paper argues that adaptation is already taking place in a piecemeal manner across Europe, therefore a more strategic approach is needed to ensure that timely and effective adaptation measures are taken, ensuring coherency across different sectors and levels of governance.

Next to a number of other fields, the proposed EU framework of the White Paper includes objectives and actions to increase the resilience of EU water systems. Specific emphasis is given to the proper implementation of the WFD, the Floods Directive as well as the Water Scarcity and Droughts Strategy for the delivery of adaptation with regard to water.

The following specific water-related actions (on EU and Member State level) are proposed:

- Develop guidelines and a set of tools (guidance and exchange of best practices) by the end of 2009 to ensure that climate change is built into further implementation of River Basin Management for the WFD.
- Ensure that climate change is taken into account in the implementation of the Floods Directive.
- Assess the need for further measures to enhance water efficiency in agriculture, households and buildings.
- Explore the potential for policies and measures to boost ecosystem storage capacity for water in Europe.
- Look for possibilities to deliver adaptation action which deliver multiple-benefits for flood risk management, water scarcity and drought management and river basin

[4] Water scarcity and droughts - Council conclusions, 13389/07 ENV 486 DEVGEN 170 AGRI 307, Brussels, 15 October 2007.

management through better alignment of planning and implementation and catchment based approaches.

- Establishing a Clearing House Mechanism as a database on climate change impact, vulnerability and best practices on adaptation.
- Explore the possibilities to improve policies and develop measures which address biodiversity loss and climate change in an integrated manner to fully exploit co-benefits and avoid ecosystem feedbacks that accelerate global warming'.
- Draft guidelines on dealing with the impact of climate change on the management of Natura 2000 sites.

4.5 Other relevant EU policies and legislation

The following EU policies are considered relevant for climate change adaptation and river basin management. Some of them include tools to incorporate climate change impacts, others still may need to be refined to contribute to climate change adaptation related to river basin management.

The **EU marine and coastal policy** is also relevant to adapting to climate change with regard to water issues. In particular the Marine Strategy Framework Directive (2008/56/EC), which requires the achievement of good environmental status of the EU's marine waters by 2020, provides an additional planning framework for adaptation. Effective implementation of this Directive will help increase resilience in the marine environment and facilitate adaptation efforts.

In addition, the White Paper on Adaptation asks for action to ensure that adaptation in coastal and marine areas is taken into account in the framework of the Integrated Maritime Policy as well as the reform of the Common Fisheries Policy.

Specific developments related to reducing the impacts of climate change by implementing **EU policy on renewable energy** (e.g. hydropower development, biomass production) may have impacts on aquatic ecosystems, particularly when such activities either do not recognise or take insufficient account of environmental protection as part of the multi-purpose uses of water bodies. On the other hand, requirements to protect the water environment might impact the potential of certain climate change mitigation measures. Therefore, a well-balanced approach of all relevant EU policy is needed to meet both climate and water protection objectives.

A well-balanced approach with **EU transport policy** is also needed to meet both climate mitigation and adaptation and water protection objectives. With emissions of greenhouse gases from transport still on the increase, a shift from high-carbon road transportation to low-carbon maritime and inland shipping is encouraged by EU transport policy as both modalities contribute relatively positively to reducing overall climate change impacts from transport. On the other hand, navigation on rain water fed rivers will become increasingly vulnerable to climate change impacts such as more varied precipitation patterns. A balanced approach should therefore ensure that both climate mitigation and adaptation and environment protection aspects are checked and reported for transportation projects with environmental implications as well as for environment projects with transport implications in environmental impact assessments (EIAs) and strategic environmental assessments (SEAs). Such a multi-disciplinary policy should guarantee actions that provide an optimum between mitigation and adaptation.

Agriculture can also make a contribution to adaptation. Thus, policy coherence with the **EU Common Agricultural Policy**'s provisions should be ensured with regard to adaptation objectives in water management.

In addition, proper soil management is expected to play a key role in the climate change efforts. Considering also the close interaction of the soil environment with the water environment, current **European policies for soil protection** should also be considered in the context of adaptation efforts in the water management sector (Soil Thematic Strategy (COM(2006) 231), proposed Soil Framework Directive (COM(2006) 232).

The **strategic environmental assessment (SEA)**, either alone or as part of a sustainability appraisal, can help to ensure that plans and programmes take full account of climate change issues. The SEA Directive (2001/42/EC) requires identification and evaluation of plan impacts on a number of environmental issues, including climatic factors; and, where appropriate, to put measures in place to minimise and respond to significant impacts identified[5]. Possible related SEA climate change objectives related to adaptation could include measures such as:

- Ensuring that drainage systems can cope with changing rainfall patterns/intensity
- Taking a precautionary and risk-based approach to developing in the floodplain
- Ensuring adequate future water supply and demand management
- Avoiding actions that limit future adaptation

More details on the possible role of SEA in climate change adaptation is provided in Annex VI.

The European Commission's communication on an **approach on the prevention of natural and man-made disasters** COM(2009) 82 final, was issued in February 2009 and sets out the framework for a strategy on prevention with links between the steps in the risk management cycle; prevention, preparedness, response, recovery and lessons identified to create conditions for developing a knowledge based disaster preventive policy at all levels of government. Between 1990 and 2007 the European Union witnessed a marked increase in the number and severity of both natural and man-made disasters. The loss of human life, the destruction of economic and social infrastructure and the degradation of already fragile ecosystems is expected to worsen as climate change increases the frequency and magnitude of extreme meteorological events, such as heat waves, storms and heavy rains.

4.6 Relevant adaptation initiatives in Member States

Annex VII of this Guidance refers to important information hubs on Member State level concerning national adaptation initiatives which may also refer to water measures (e.g. webportals on climate change and river basin management). The Commission will make further information on EU and Member State adaptation activities available at a central adaptation homepage: http://ec.europa.eu/environment/climat/adaptation/index_en.htm

A European Climate Change Adaptation Clearing House is under preparation by the EC that will contain the updates of national adaptation strategies in the future.

[5] A report published in Summer 2007 called "Strategic Environmental Assessment and Climate Change: Guidance for Practitioners suggests how climate change issues can be considered in SEA". It presents information on the causes and impacts of climate change and how they can be described and evaluated in SEA. It also describes how adaptation and mitigation measures can be developed through SEA.

5 CLIMATE MODELLING, PROJECTIONS, SCENARIOS, POTENTIAL IMPACTS AND UNCERTAINTY

This chapter aims to provide first guidance on how to handle available scientific knowledge from models, projections and scenarios on climate change as well as related uncertainties for the purpose of river basin management.

It provides a concise summary of available global models, of projections and scenarios with emphasis on their strengths and weaknesses, as well as a general overview of the main predictions for climate change impacts on water resources across Europe. A set of guiding principles is proposed for decision-making and management of the water environment in the light of climate change and uncertainties.

This chapter refers to further sources of reading for those who are interested in climate modelling and projections. This chapter's aim is restricted to providing a general overview of the state of play of knowledge, which may serve as a sufficient basis for the subsequent chapters on EU water policy and climate change adaptation.

5.1 Models, projections and scenarios

Guiding principles

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.

5.1.1 Global level

In order to grasp the potential range of future climate change, several **global climate projections** are conducted – in international coordination – each of them applying different emission scenarios as well as different global climate models.[6] The results are interpreted, described and published on a regular basis by the Intergovernmental Panel on Climate Change (IPCC). The IPCC recently published its fourth Assessment Report (AR4) "Climate Change 2007" (IPCC 2007). The publication of the 5th report (IPCC AR5) is planned for 2013 (WG I - Report on the Physical Science of Climate Change).

The new generation of global climate models (Atmospheric and Oceanic Global Circulation Models - AOGCM) are more reliable than their predecessors. *Important improvements are, amongst others, the consideration of relevant land surface processes and a database of the earth's surface qualities*. Additionally, the calculation of cloud formation processes has been revised and additional information is obtained as output due to the higher resolution of the new models. Further improvements of the next generation of global climate models are being planned. For example, there are plans to take land ice into account in the calculation of land surface processes.

[6] Please refer to Annex IV for concise definitions of the terms "projections", "forecasts" and "scenarios".

However, it should be kept in mind that global models are based on many simplifications and assumptions, so that their results bear a degree of uncertainty. In addition, the coarse spatial resolution of global models is insufficient for application in impact models and thereby for determining the effects of regional and local climate change. To overcome this limitation, regionalisation procedures are applied. By these, the global projections are "downscaled" to smaller grid elements of up to 25 km × 25 km; in individual studies the downscaling is even below this grid size, or adjusted to the locations of individual stations.

5.1.2 Climate change projections for the EU

Data-comprehensive analysis and synthesis of regional climate change on the European scale was carried out in the last decade by the EU projects PRUDENCE, STARDEX, the still ongoing project ENSEMBLES and the projects CECILIA and CLAVIER on Central and Eastern Europe (details on these research projects are provided in Annex II).

The project PRUDENCE has provided a series of high-resolution climate change projections for 2071-2100 for Europe, characterising the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. The ENSEMBLES project has extended and updated this approach integrating climate change impact studies into an ensemble prediction system.

The STARDEX project has given a rigorous and systematic inter-comparison and evaluation of downscaling methods for the construction of regional scenarios of extremes. The aim was to identify the more robust techniques, and to use these to produce future scenarios of extremes for European case-study regions for the end of the 21st century. Large progress was made regarding the vital question as to whether extremes will occur more frequently in the future.

The EU project CECILIA provides detailed regional climate projections (and impact assessments) for Central and Eastern Europe, similarly to the EU project CLAVIER which focuses on Hungary, Romania and Bulgaria.

Summarised information on observed and projected climate change in the EU is also available from the European Environment Agency (please refer to EEA/JRC/WHO (2008) and section 0 of this Guidance for a brief summary of key projected impacts).

5.1.3 National to local level

Currently, many national and European research activities are producing relevant and valuable results on climate change impacts on Europe's fresh, transitional and marine waters (many research projects that are relevant to climate change impact studies on water are briefly outlined in Annex II). Some Member States have also carried out their own more localised modelling (e.g. UK Climate Projections (UKCP09)). Please check Annex V for further web links on Member State local climate projections.

Although the results from research activities developed at local level can in some cases be very useful, it is recommended that the information used in the planning processes be obtained and validated at a national level by the competent authorities, so as to ensure adequate homogeneity in the treatment of different geographic areas. For instance, the Spanish Meteorological Agency (AEMET) has published Regionalized Scenarios for Climate Change Impact Assessment, and disseminated this data through its web site, in order to cope with the implementation of climate change strategies at all policy levels.

Quantitative projections of changes in precipitation and river flows at the river-basin scale remain, however, uncertain, due to the limitations of climate models, as well as scaling issues between climate and hydrological models. Nonetheless, in recent years, the resolution of regional climate model simulations has increased considerably. In addition, statistical correction methods have been developed which bring the models closer to a realistic simulation of, for instance, the amount and intensity of precipitation at the scale of river basins and small catchments.

Example 5a: Downscaling methods in France

Different statistical downscaling methods have been implemented and evaluated to generate local precipitation and temperature series, at different sites in France, based on the results from a variable resolution general circulation model[7]. These methods are being tested over various French river basins (Seine, Loire, Garonne), and could be used elsewhere.

Example 5b: Downscaling in the Thames Basin, UK

The Thames Estuary TE2100 project produced an integrated set of dynamically downscaled data for the Thames Basin over a 150 year period. This showed results from a runoff model driven by precipitation data from the same regional model, which was used to produce simulations of storm surge in the North Sea. This is a good example of high-resolution integrated modelling. It also fed into the UKCP09 marine projections.

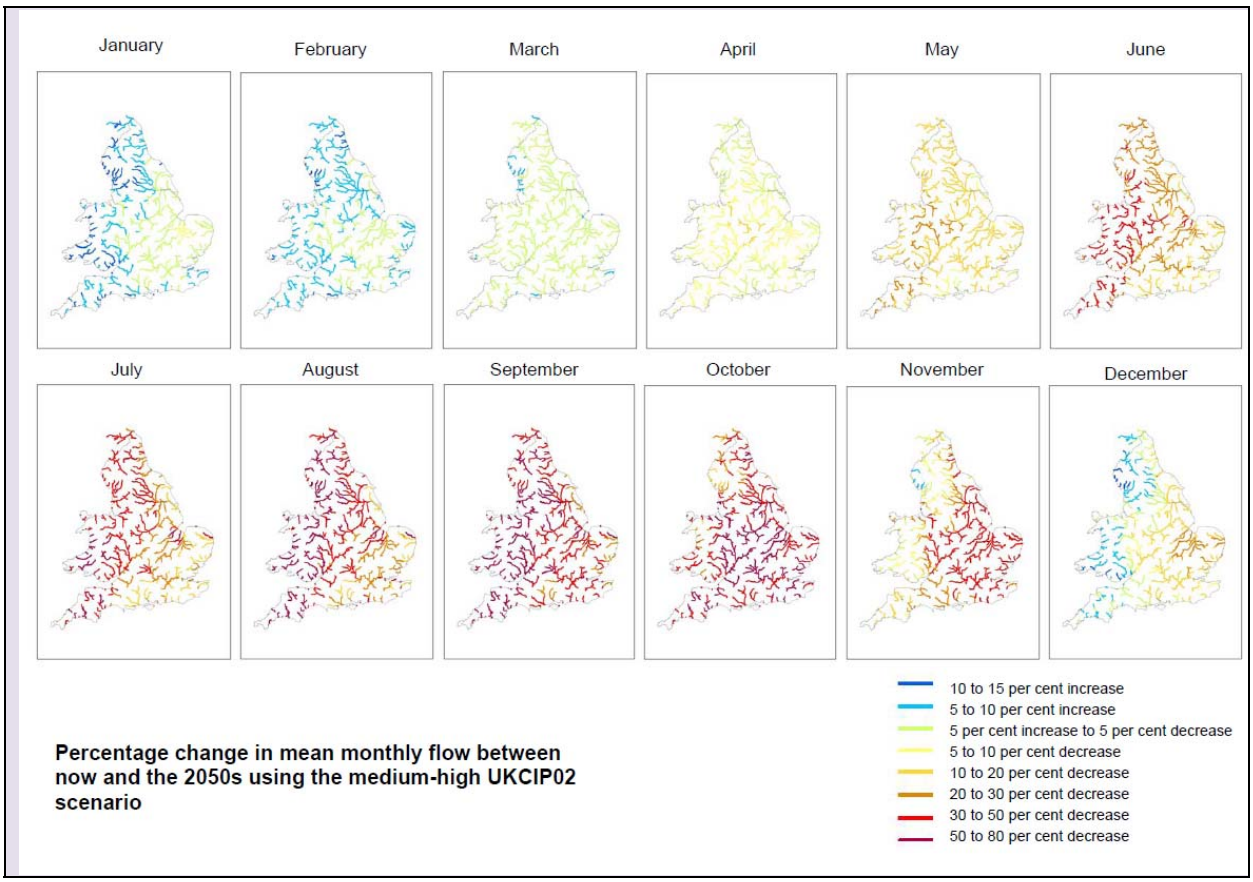
Example 5c: Change of flow between now and the 2050s in the UK

The figure below shows the results of estimation of river flows in the 2050s that were carried out using the Continuous Estimation of River Flows (CERF) model. This is a regionalised rainfall-runoff model developed by the Environment Agency of England and Wales and the Centre for Ecology and Hydrology. The model uses time series data of precipitation and potential evaporation demand to model time series of daily river flows.

The study is the first to use catchment-level models to look at river flows across the whole of England and Wales. Its finding that total annual river flow could drop by as much as 10–15 percent by the 2050s is a result of lower summer and autumn river flows and higher winter river flows.

These results show a possible decrease in mean monthly river flows during the summer and autumn months of around 50 percent, with a fall of up to 80 percent in some areas. They also show a corresponding increase in mean monthly river flows during the winter months of up to 15 percent.

[7] Boé et al, 2006 ; Déqué et al, 2007.



Example 5d: Bias correction methods in the Rhine Basin

By definition a model can only approximate reality and will therefore always be biased. Current climate model versions resemble reality much better that earlier versions. Nevertheless, their results cannot be used in impact models directly, unless they are corrected.

Focussing on precipitation output of various climate models and their application in hydrological models of the River Rhine, different statistical bias correction methods are being applied in current cross-bordering projects (KLIWAS, AdaptAlp, and RheinBlick2050). They are tested on different spatial scales, in topographical regions and with focus on mean and extreme values. The methods are also applicable in other catchments. From the KLIWAS project corrected data will be available for all national and international catchments of Germany.

Example 5e: Downscaling national-regional patterns in precipitation to a local level – Production of a local weather generator in Sweden

Within the project 'Extreme rainfall events in Sweden and their importance for local planning' two main tasks have been the focus: a) identifying trends of precipitation extremes in Sweden using daily precipitation observations from 220 stations during the period 1961-2004, and b) projecting future changes in the extremes over the next 100 years by using a weather generator developed for Sweden. Extreme precipitation is expressed in terms of eight indices, which are chosen from a much larger set of possible indices based on the discussion between the authors and the reference group of the project. They describe specific aspects of extreme precipitation considered to be important for Sweden. These also include indices quantifying means as well as dry conditions. All indices are calculated based on daily precipitation from measurements or simulations by the weather generator developed in this project.

The results for the trend analysis are generally in line with results from other studies concluding that regions at middle and higher latitudes are getting wetter and extremes are becoming more frequent

and more intense. Separate trend analysis for the different seasons show that climate mainly gets wetter in winter, spring and summer, while decreasing trends could be observed at many stations in autumn.

By following the steps in the weather generator, future extreme precipitation at local scale in Sweden under the SRES A2-scenario is obtained and presented. As expected, the changes vary from station to station within a short distance, further demonstrating the need of downscaling from GCM scale to local scale. However, an overall trend of increased frequencies and intensity of the extremes can still be identified for the majority of the stations studied. The developed downscaling methodology is relatively simple but useful in deriving local precipitation changes including changes in the extremes for local application.

Sources:

Achberger, C. and D. Chen, 2006: Trend of extreme precipitation in Sweden and Norway during 1961-2001. Earth Sciences Centre, C72. Earth Sciences Centre, Göteborg University, Gothenburg, 58 pp.

Deliang Chen, Christine Achberger, Ulrika Postgård, Alexander Walther, Yaomin Liao, Tinghai Ou, 2008: Using a weather generator to create future daily precipitation scenarios for Sweden. www.msbmyndigheten.se

5.2 Potential impacts of climate change on the status of water resources

Water is intricately linked with climate through a large number of connections and feedback cycles, so that any alteration in the climate system will induce changes in the hydrological cycle. Global warming augments the water-holding capacity of the air and amplifies evaporation. This leads to larger amounts of moisture in the air, an increased intensity of water cycling, and changes in the distribution, frequency and intensity of precipitation. Consequently, the distribution in time and space of freshwater resources, as well as any socio-economic activity depending thereon, is affected by climate variability and climate change. For the coming decades, global warming is projected to further intensify the hydrological cycle, with impacts that will probably be more severe than those so far observed (EEA/JRC/WHO, 2008).

Potentially all quality elements included in the definition of WFD qualitative and quantitative status of water are sensitive to climate change. Over its impact on the quantitative and qualitative status of water resources, climate change affects the following variables:

- water availability (river flows and groundwater levels);
- water demand (esp. peak demands during periods of drought);
- intensity and frequency of floods and droughts, and of strong stream or low flow conditions;
- surface water quality, including temperature, nutrient and other contaminants content;
- biodiversity in aquatic systems;
- groundwater quality.

From the several national and European research activities there is limited empirical evidence to demonstrate impacts unequivocally, because of difficulties in disentangling the effects of climatic factors from other pressures. On the other hand, there are many indications that freshwaters that are already under stress from human activities are highly susceptible to climate change impacts and that climate change may significantly hinder attempts to restore some water bodies to good status in the long term.

- **Water availability and water demand**

Climate change is projected to lead to major changes in yearly and seasonal water availability across Europe in the second half of the century. According to current results, summer flows are projected to decrease in most of Europe, including regions where annual flows will increase. Annual river flow is projected to decrease in southern and south-eastern Europe and increase in northern Europe, but absolute changes remain uncertain. Climate change is projected to result in strong changes in the seasonality of river flows across Europe (EEA/JRC/WHO, 2008).

Regions in southern Europe which already suffer most due to water stress are projected to be particularly vulnerable to reductions in water resources due to climate change. In addition, higher temperatures are expected to lead to increased water demand, especially for irrigation and urban supply. This will result in increased competition for available resources (EEA/JRC/WHO, 2008).

In addition to river flows, groundwater would also be under pressure due to climate change. In particular, additional pressure will be due to sea-level rise, shrinking land ice and permafrost areas, declining groundwater recharge (especially in southern European countries), more extreme peak flows and more prolonged low flows of rivers, and increased groundwater abstraction. Regions with higher precipitation may experience rising groundwater levels that may affect houses and infrastructures (EEA/JRC/WHO, 2008).

- **Floods and droughts**

With an intensified hydrological cycle, the intensity and frequency of flood events are projected to increase in large parts of Europe, although estimates of changes remain highly uncertain. Especially flash and urban floods triggered by intense local precipitation events are likely to be more frequent throughout Europe. Projections suggest that warming would result in less snow accumulation during winter and therefore a lower risk of early spring flooding (EEA/JRC/WHO, 2008). Some projections at river basin scale also suggest that the spring flooding period (related to snow melt) could occur earlier. In autumn, flood risks could increase because of reduced water storage (snow accumulation) (Etchevers et al., 2002).

Climate change is also projected to increase the frequency and intensity of droughts in many regions of Europe, as a result of higher temperatures, decreased summer precipitation, and more and longer dry spells. The regions most prone to an increase in drought hazard are southern and south-eastern Europe (EEA/JRC/WHO, 2008).

- **Water quality and biodiversity in aquatic systems**

Water quality may be impacted by climatic changes in temperature and precipitation (EEA/JRC/WHO (2008)). A rise in water temperature will affect the rate of biogeochemical and ecological processes that determine water quality. This may result in:

- *Reduced oxygen content*. Increases in water temperature in streams and lakes reduce oxygen saturation concentration and increase biological respiration rates, and may therefore result in lower dissolved oxygen concentrations, particularly in summer low-flow periods and in the bottom layers of lakes. Higher temperature and lower oxygen concentrations will cause stress for, and may reduce the habitats of, cold-water species such as salmonid fish in lakes and rivers.
- *Less ice cover* - earlier ice break-up and longer ice-free period in rivers and lakes.
- *More stable vertical stratification and less mixing of water in deep-water lak*es, which in turn will affect deep-water oxygen conditions, nutrient cycling and plankton communities.
- *Eutrophication.* A warmer climate could generally enhance the pollution load of nutrients in surface and groundwater. Higher temperatures would increase mineralisation and releases of nitrogen, phosphorus and carbon from soil organic matter; higher rainfall intensity will increase run-off and erosion, which will result in

increased pollution transport. On the other hand, higher soil moisture deficits would reduce mineralisation. In addition, release of phosphorus from bottom sediments in stratified lakes is expected to increase, due to declining oxygen concentrations in the bottom waters.

- *Change in timing of algal blooms and increase of harmful algal blooms*.
- *Alterations to habitats and distribution of aquatic organisms*. The geographic distribution of aquatic organisms is partly controlled by temperature. Higher water temperatures can lead to changes in distribution (species moving northwards (in Europe) and to higher elevations) and may even lead to the extinction of some aquatic species. In the Mediterranean region, numerous ephemeral aquatic ecosystems are projected to disappear and permanent ones to reduce in size.
- *Climate-induced changes in sediment quality and quantity.* Sediments form an integral part of natural aquatic systems, providing a substrate for organisms and playing an essential role (e.g. through nutrient cycling). However, contaminants can become adsorbed to sediment. Climate-induced changes in extreme weather conditions (and associated processes such as currents and erosion) could expose and remobilise sediment-associated contamination, or could result in high-energy mass flows of eroded soil or remobilised sediment, in turn impacting aquatic ecosystems.

- **Groundwater quality**

Fresh groundwater bodies will become more vulnerable to pollution through reduced turnover times and accelerated groundwater flow. Saline intrusion in coastal aquifers, making the water unsuitable for drinking, may be exacerbated by future sea-level rise. Finally, further increases in groundwater temperature will raise the salinity of groundwater due to increased evapotranspiration losses, increased soil CO2 pressures and increased water — rock interaction (EEA/JRC/WHO, 2008).

Due to density effects a sharp fresh-water/sea-water interface separates freshwater from seawater. The position of this interface can be influenced by a rise of the sea level in two ways. First, this interface will rise with the sea level and second, increasing water abstraction e.g. in order to compensate the sea level rise by more intense drainage activities can lead to an uplift of the interface between seawater and freshwater as well. This uplift of the interface can be accelerated in areas where freshwater is used for water supply or irrigation purposes and harm the quality in any extraction well.

In areas where river flow and groundwater recharge may decrease, e.g. in southern Europe, water quality could also decrease due to lower dilution of pollutants. Similarly, higher intensity and frequency of floods and more frequent extreme precipitation events are expected to increase the load of pollutants (organic matter, nutrients, and hazardous substances) washed from soils and overflows of sewage systems to water bodies.

Finally, in some estuarine and coastal water bodies including coastal lagoons, there may be local changes in ecology resulting from increased saline intrusion associated with sea level rise.

5.3 Managing the water environment based on uncertainty of projections and scenarios

Guiding principles

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.

Understanding the sources of uncertainty

As already indicated above, climate change models and projections are based on many simplifications and assumptions, so that their results bear various uncertainties. From the perspective of climate impact research, the various sources of uncertainty can be grouped into two categories:

(i) uncertainties related to incomplete knowledge about the system under investigation (e.g. due to measurement errors or simplifications in model formulations).

(ii) uncertainties inherent to the system under investigation (e.g. due to a chaotic behaviour of the global climate or the socio-economic system).

Current and future improvements in measurement networks and model formulations can only minimize uncertainties of category (i). It is presumably unrealistic to believe that uncertainties will be completely eliminated in future climate projections.

As there will never be a single "true" model, multiple model concepts should be used in a comparative way ("*multi-model-approach*"). For instance, in the case of floods, the different models and projections have shown in some cases a large error in the generation of high extreme values of precipitation, so that the estimated impacts based on them could have a great uncertainty. In some of these cases, a multi-model approach will provide more robust estimates of changes in extreme precipitation and flood events, as well as the opportunity to quantify uncertainty inherent to the use of different scenarios. In the case of coastal flooding, there may be a need for common scenarios as regards for instance sea level rise, which could facilitate planning. On the other hand, elements such as increased storminess have a local component that makes common scenarios have less sense for them.

Example 5f – The KLIWAS project – Analysing uncertainty

The interdisciplinary research programme KLIWAS (www.kliwas.de) integrates ecological, economical, water quality and water quantity aspects of climate change for rivers and coastal waters which are used as waterways. KLIWAS strictly follows a multi-model-approach. It uses and evaluates up to 30 climate model runs (including those of the EU-FP6-Project ENSEMBLES and new runs provided by the KLIWAS group), as well as different bias correction methods and hydrological models, in order to account for different sources of uncertainty and provide a reliable basis for the assessment of various adaptation options. With the purpose of model validation and monitoring of climate change effects, historical data bases are extended, too. A model chain is established, which couples climate models to hydrological/oceanographic, hydrodynamical/sedimentological, water quality, and ecosystem models.

At each step, uncertainty is analysed in detail to assess the level of understanding of the aquatic systems and their sensitivity to low flow, floods, and other aspects of "historical" and future climate change. Changes and possible adaptation measures of the waterways are evaluated taking all functions of rivers and coastal waters into account. Thus, varied WFD relevant information is provided.

The inevitable uncertainties of category (ii) are better addressed when more model simulations are included in a so called *ensemble* (*ensemble-approach*). Ensembles help to approximate the probabilistic characteristics of the modelled system. From the ensemble of simulations, relevant information can be extracted, e.g. by using scenario techniques. Nevertheless, difficulties arise when deriving conclusions from an ensemble of projections that are not really equiprobable.

Handling uncertainty

In practical terms, decisions related to climate change, its impacts and adaptation options cannot be made on simple, single values but need to encompass the range of possible future climate projections. Thus, decision makers will have to handle a bandwidth of values or different scenarios and accept and be explicit about uncertainty.

This could be through looking at the range of projections from the different models to see which results are consistent and for which we can be confident about. As an example, if all models indicate that it will get wetter in June, then we might be more confident about this projection. If the relevant results are more varied, e.g. it may get wetter or drier, then it is important to choose adaptation options which will be effective across the range of potential future changes. This might involve increasing the resilience of the system, its adaptive capacity, and the use of no-regret measures rather than options which rely on the direction of change.

The choice and priority of measures should be based on the vulnerability of the system. Research can determine which sectors are impacted most severely by climate change and where measures are needed most urgently to prevent undesired effects, even if their exact extent is not yet known.

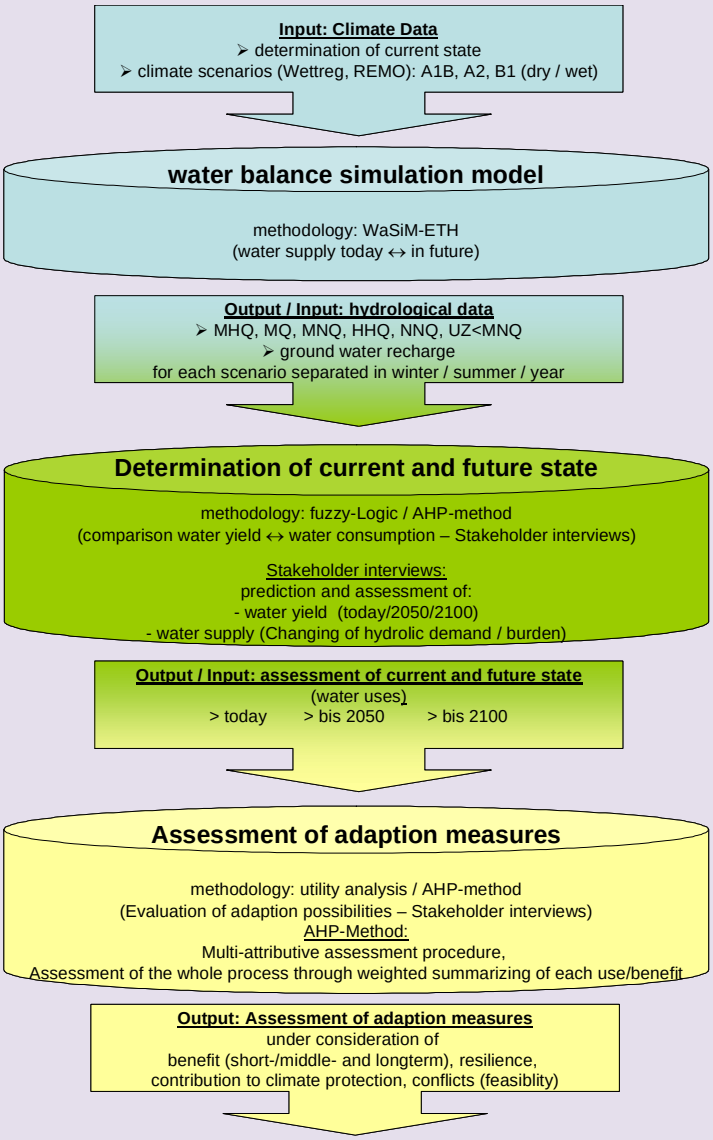
In general, adaptation to climate variability and change is both a technical and a social process of assessing and responding to present and future impacts, planning to reduce the risk of adverse outcomes, and increasing adaptive capacity and resilience in responding to multiple stresses. A key step is to make use of the best available science to identify conditions and risks, as well as their relevance for adaptation strategies and actions, to allow adapting to new boundary conditions due to climate change.

Any analysis carried out as part of river basin management planning should take into account the existence of uncertainty and, where possible, use a range of climate projections including a variety of emissions scenarios, global and regional climate models, and model runs. Thus, results will handle a range of possible impacts on pressures from climate change. Where these ranges are large, it is useful to consider the analysis as a narrative for likely future conditions. In many cases, it will be useful to take a bottom-up approach in terms of looking at potential measures and considering how each of these or combinations of these will perform against the range of possible climate futures modelled. In chapter 7.7, further guidance is given on how to choose measures that are robust and flexible vis-a-vis future climate conditions (including no-regret, win-win and low-regret measures).

Specific guidance on the issue of management under uncertainty is also given in chapter 8 on flood risk management in the context of uncertainty and chapter 9 on water scarcity and droughts. The example of the research and development project WASKLIM is presented below, which aims to develop a concise method that allows decision-making under uncertainty on the basis of adaptation capacities and vulnerabilities.

Example 5g: WASKLIM - Adaptation strategies in water management (state of play – June 2009)

The currently finished Research and Development Project aims to develop a concise method that allows taking decisions under uncertainty on the basis of adaption capacities and vulnerabilities. Therefore, model simulations of the water balance (WaSiM-ETH), including simulations of scenarios for 2050 und 2100, have been performed for three pilot areas (based on regional models WettReg und REMO). In parallel, regional conferences in these pilot areas, questionnaires and expert interviews collected expert knowledge about the vulnerability of respective water uses. These results were fed into a fuzzy logic-based decision support system (DSS).



The combination of expert knowledge with the simulation results of further climate change effects creates the basis for the assessment of adaption measures.

As a result the DSS gives statements which water use shows a priority need of adaptation action as well as a pre-selection of suitable adaptation strategies.

The DSS delivers a useful building block for dialogue and participation processes. In a first step this approach requests an intensive reflection of the basic conditions for different water uses. This includes an analysis of the vulnerability of these uses, decoupled from the results of climate impacts modeling. In a second step climate projections are added. In this way this approach shows the need of action through the overlapping of the spread of the modeling results and operating range given by the expert statements. How stable the priority and the recommendations on specific adaption measures, which are outcomes of the DSS, are, can be tested by sensitivity analyses. Hence, the whole decision process can be made transparent and open for participation and public discussion.

Example 5h: The CC and Vulnerability Committee in Sweden based their work on the assessment of global climate change made by the UN's climate change panel, the IPCC.

In order to highlight vulnerability in a future climate, they are using a number of global scenarios for climate change. These comprise two global climate models and two global emissions scenarios from the IPCC. Based on these four scenarios, the Rossby Centre at the Swedish Meteorological and Hydrological Institute (SMHI) has made calculations using its regional models.

In consultation with the committee and various sectors, SMHI has developed around 40 specific climate indices as the foundation for assessing the future vulnerability of the sectors. A total of over 10,000 climate maps showing the development of the indices have been drawn up. The calculations have been made for various timeframes – 2020s, 2050s and 2080s. Data has also been produced for

the trend over the past 15 years. They have constantly compared the future climate with the most recent complete reference period used in climatological contexts (1961–1990).

The scenarios analysed indicate dramatic changes in Sweden's climate at the end of the century. The winter climate near overall in Sweden will be similar to that which is currently found in northern France. Precipitation almost in the whole of the country will increase in the autumn, winter and spring. The summers will most likely be warmer and have a drier climate, particularly in southern Sweden. Torrential rain will become more intensive.

Finally, it should be kept in mind that in some Member States, "climate services" are set up to help bridge the gap between climate models/scenarios and decision-making. Please see examples given in the box below.

Example 5i: "Climate services" in some Member States

UK:

There is considerable guidance on decision making, uncertainty and use of probabilistic climate projections in the UK. Please check: http://ukclimateprojections.defra.gov.uk

Germany:

Germany has a newly established climate service centre. Please check: http://www.climate-service-center.de/

France:

A French project called DRIAS, whose purpose is to give broad access to climate change scenarios and simulations for impact and adaptation studies, has been launched in 2009 (within the GICC program, managed by Météo-France).

Finland:

In Finland, Watershed Simulation and Forecasting System (WSFS) is used both for hydrological climate change scenario simulations to estimate the impact of climate change on floods, droughts and water resources, and to assess the adaptation possibilities of water resources management. The results have been disseminated through publications, seminars and catchment specific project reports to stakeholders. WSFS is also used for real time hydrological forecasting and lake regulation planning, disseminated to stakeholders and even operated by stakeholders through internet (www.environment.fi/waterforecast), to be used in flood and water resources management.

The VACCIA-project (2009-2011) is based on data from intensively studied sites/sub-regions of the FinLTSER-network. The sites have a wealth of existing information, and are closely integrated into the local-scale economy and activities. This provides the link to the scale where realistic adaptation measures can be planned and assessed. The project will provide both detailed descriptions about the methodology and tools for making climate impacts and adaptation assessments, as well as an inventory of realistic adaptation measures for key ecosystem goods and services. This methodology and information can be used by stakeholders at local, regional, national and international scales.

In addition, FINESSI (http://www.finessi.info/finessi/index.php) is a web tool that allows the user to explore the possible impacts of climate change in Finland on chosen impact areas and at different time periods up to the end of the 21st century. The tool is intended for planners and researchers, but it may also be of interest to students and to members of the public. FINESSI offers a common platform for integrating observations of the present-day climate and environment with modelled information about future climatic conditions (scenarios) and their impacts. The impacts of climate change are presented for climate-sensitive systems and activities such as agriculture, water resources and natural ecosystems.

Czech Republic:

Useful information can be found on the following sites:

- CHMI (Czech Hydro Meteorological Institute): http://www.chmi.cz/cc
- National Climate Program of the Czech Republic: http://www.chmi.cz/nkp/nkp.html
- Ministry of the Environment: www.env.cz

6 GETTING STARTED: HOW TO BUILD ADAPTIVE CAPACITY FOR MANAGEMENT UNDER CLIMATE CHANGE

6.1 Introduction

This chapter proposes a set of guiding principles that should help those with river basin management responsibilities in setting up a strategy for building adaptive capacity[8] to manage river basins districts under climate change.

The chapter serves to remind managers that they should consider aspects, which go beyond the handling of available scientific knowledge on climate change and related uncertainties (chapter 5), in order to carry out river basin planning and management in a changing climate (as described in the next chapters of this Guidance). "Softer" aspects of river basin management, such as awareness-raising, proper staff training and cooperation between different levels of authorities and sectors, also need to be considered in efforts to build up adaptive capacity for management under climate change.

The way climate change is incorporated in the river basin management cycle also needs to undergo public consultation (as part of the normal procedures according to WFD Art. 14), while in the same time, climate change may help in raising the public profile of sustainable water management. An efficient use of the WFD public participation process is especially relevant for climate change awareness raising in water management, but also for integrating valuable sector-specific knowledge of stakeholders.

Please note: The following list of guiding principles addresses mainly those aspects that can be influenced by those with river basin management responsibilities. The development or modification of policies and regulations, which is an equally important condition for climate change adaptation, is not addressed here.

6.2 What is needed to build adaptive capacity?

Building adaptive capacity has many aspects. Below, information is presented about using available knowledge and data in a RBD, involving the relevant stakeholders and looking out for the wider audience, and getting started in an international river basin.

6.2.1 Using ongoing research and adaptation activities to increase knowledge at river basin scale

Guiding principles

1. Link river basin management adaptation activities to national and regional climate change adaptation strategies and activities.

   Such strategies are a source of relevant research, information and assessments. They are often based on detailed assessments of climate change impacts on water and in many cases include first evaluations of potential water adaptation measures. These adaptation strategies and the assessments of impacts can supplement the climate impact assessment of the WFD (Article 5, see chapter 7).

[8] "Adaptive capacity" can be interpreted as the "ability to cope, adapt or recover from the effects of a hazard" (in this case, climate change). The presence of adaptive capacity is considered a necessary condition for the design and implementation of effective adaptation strategies (IPCC (WGII), 2007).

2. Check existing relevant science and research information on climate change modelling and impacts in the river basin.

   This could include, for example, producing information inventories, meta-databases and web-pages. Please refer to chapters 5, **Error! Reference source not found.**, **Error! Reference source not found.** and Annex I of this Guidance for a summary of key European information networks, an overview of key research projects and databases or toolkits on adaptation actions/measures.

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.

   Adaptation to climate change will be required across Europe. Possible future impacts in one river basin might represent the current situation in another one, and useful adaptation experience in other regions/RBDs with similar characteristics may exist. It is important to exchange knowledge and experiences with other regions/RBDs on a regular basis and integrate lessons learned.

In general, the knowledge gaps that can be addressed by water managers at the RBD level are not related to gaps in the science of climate change and water, but to *what the current state of knowledge means for their particular RBD.* This means that often river basin managers need to make use of available research and experience. In addition, relevant local knowledge should be developed to the extent possible, such as predictions of climate change impacts in the basin for various future climate scenarios. Please check also the recommendations of chapter 5 on how to handle available scientific knowledge and uncertainties about climate change.

6.2.2 Data collection and building of partnerships

Gaining political backing and embedding climate change adaptation in river basin management planning requires the following two key features:

- Collecting appropriate data to improve decision making and develop a sound adaptation strategy.
- Identifying stakeholders and deciding on an approach to engagement as well as working in partnerships.

Collecting appropriate data to improve decision making and develop a sound adaptation strategy

Guiding principles

5. Evaluate coverage of data (e.g. meteorological, hydrological, water quality, soil moisture data, stake, damage cost data, etc), particularly considering the following issues:

   - Does present data collection cover both current data and monitoring requirements as well as future requirements under changed climate conditions?
   - Is present data collection robust in the face of possible changes in underlying variables that define typologies and, therefore, reference conditions?
   - Does current data collection and monitoring provide adequate monitoring of climate change impacts? Does current data collection and monitoring provide

monitoring of the effectiveness of adaptation measures?

- Are historical data sets coherent and consistent in view of e.g. changes of measurement methods over time? If problems of coherence are identified, can these be dealt with to achieve reliable historical data series?

6. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders.

All in all, adapting to climate change implies new requirements regarding the type and the extent of data collected for river basin management. Long time series are judged essential for understanding the evolution of physical variables and selected species over time. On the issue of WFD monitoring under climate change, please refer to chapter 7.4 for more detailed guidance and suggested actions.

Identifying stakeholders and deciding on an approach to engagement – Working in partnerships

Guiding principles

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 other sectors which are directly related to water management (e.g. agriculture-water demands, water needs for energy production, etc). Keep in mind that, in the context of the RBMP preparation, it is not possible to carry out all studies necessary to determine the evolution of these factors for the different climate scenarios.
10. Integrate cross-sectoral delivery of adaptation measures and coordinate activities with land use planning.
    Establish links of river basin management planning to other national and regional planning activities and policies which are relevant to climate change impacts and adaptation in RBDs (e.g. municipality planning, spatial planning, land use planning).
    Within river basins and catchments, integrate adaptation actions with those of other sectors to develop holistic plan that takes advantage of cross-sectoral adaptation benefits – eg reinstating floodplain wetlands that prevent flooding, retain water and provide wildlife habitat.

Meaningful and early stakeholder engagement can improve acceptance of decisions and measures and thereby increase the feasibility of the adaptation strategy. Evidence and analysis is often more accurate when carried out in conjunction with stakeholders.

Integration refers to all sectors in order to avoid negative cross-sectoral feedbacks of measures (or non-action in one sector) but also to the different levels of management within an RBD, including different kinds of authorities. Therefore, it is important to carry out a 'Stakeholder Mapping' exercise before seeking to engage stakeholders in the adaptation process in order to identify the full range of stakeholders. Based on the list of identified stakeholders, the availability of resources and preferences or experiences, an approach to stakeholder engagement should be decided. This would result in the production of an

engagement strategy, setting out the objectives for and means of stakeholder engagement and a clear definition of the roles and responsibilities of each authority and stakeholder.

As concerns coordination with land use planning, it should be kept in mind that land use practices and land use planning have a major impact on water scarcity, floods and modification of water bodies. In several cases, co-benefits or win-win situations between the spatial planning and improving the ecological status are possible such as making room for the river (see Example 6b on the EU project ESPACE, Example 7r on making room for the river and Example 9d on Dutch planning of measures for sustainable freshwater supply including land use planning).

Example 6a – Institutional arrangements for assessing climate impacts on pressures in Austria

Austria is situated in a transitional zone with the high-precipitation area of the Alps on the one hand and the more drought prone eastern parts on the other hand. Within the alpine region an increasing future precipitation to the north and decreasing precipitation to the south is foreseen. However, due to high spatial variability of climatic conditions and hydrological processes the Alps are likely to show marked seasonal variations of precipitation.

An interdisciplinary working group of the Austrian Water and Waste Management Association (ÖWAV) and the Federal Ministry for Agriculture, Forestry, Environment and Water Management (BMLFUW), involving different stakeholders, was set up to collect multidisciplinary information on possible effects of climate change on Austrian water management and to estimate its significance. The final results of the working group were presented to the public and published as a report *Effects of Climate Change on the Austrian water management* at the end of 2008[9].

An example of the output of this working group is the assessment of climate change effects on heavy rainfall events and floods. The FLOOD Risk II project revealed that so far there have been no significant changes for medium and large catchment areas (> 250 km²) but indicated a need for action in smaller catchment areas, where the risk for heavy rainfall events already exists. Nevertheless the resolution of existing climate models is not yet high enough to get resilient results for these small areas. In high mountainous areas additional factors like the increase of sediment yield because of a rising permafrost base would have to be considered. Possible measures for the future could include:

- Guidelines for the Federal hydraulic engineering administration 2006 (RIWA-T) are considering freeboards for dams as additional safety measure against higher water levels because of climate change.
- Protect retention areas to reduce the effect of heavy rainfall events on peak flows.
- Measures to reduce soil erosion and leaching of fertilizer
- Measures to impact of increased operation of storm overflows.

Example 6b – EU project ESPACE

The European project ESPACE (North West Europe INTERREG IIIB Programme) set out to influence the philosophy and practice of spatial planning. The focus of the ESPACE (European Spatial Planning Adapting to Climate Events) project was on how adaptation to climate change can be incorporated into spatial planning systems with a special focus on water management issues. It was the first project of its kind to focus on increasing the awareness of the need to adapt to the impacts of climate change and to begin to provide some of the necessary policy guidance, tools and mechanisms to

[9] Source online: wisa.lebensministerium.at/filemanager/download/44661/

incorporate adaptation into planning systems and processes.

ESPACE was founded by a transnational group of 10 Partners spanning four North West European countries and bringing together representatives from all levels of civic society. A range of actions were undertaken by Partners to identify how to best adapt to climate change. These include actions looking at the most effective ways of raising awareness, the role of behaviour change in adapting to climate change, policy review through the use of innovative techniques and the development of tools and models.

URL: www.klimaprojekt-espace.bayern.de

6.2.3 Broadening the audience and increasing its capacities - Awareness-raising, education and training

Guiding principles

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.

An important side-effect of awareness can be the facilitation of acceptance of adaptation measures among the different stakeholders. All water-related sectors should be encouraged to become well-informed about possible impacts of climate change in their sector. The main result is ensuring preparedness, for instance through the implementation of own risk-management or adaptation measures as a consequence of increased awareness.

An additional prerequisite for building adaptive capacity for river basin management in a changing climate is learning and building up knowledge in the relevant organisations as well as the transfer of relevant knowledge.

6.2.4 Looking beyond the borders

Guiding principle

13. Develop joint or coordinated adaptation strategies in transboundary RBDs.

Transboundary basins pose particularly complex challenges with regard to the building of adaptive capacity for climate change. Joint bodies, such as international river basin commissions, should be responsible for the development of joint or coordinated adaptation strategies for transboundary basins and for following up their implementation and evaluating their effectiveness. The bodies need therefore to have the capacity and means to effectively undertake these tasks.

Further adaption to climate change might require actions outside the national part of a river basin e.g. some measure need to be taken upstream. This might require bilateral agreements based on common understanding.

Example 6c – Towards an adaptation strategy in the Rhine[10] river basin

The 1999 Rhine Convention, together with existing EU and national legislation and policies and a strong political commitment in all countries in the Rhine catchment, provide a sound basis for developing and implementing an adaptation strategy pertaining to the impacts of climate change. Activities regarding adaptation to climate change have started with an assessment. However, already in the 1990s, important measures have been taken regarding flood risk management, increasing the basin's adaptive capacity to respond to future expected climate changes.

Following the severe flooding in the Rhine in the years 1993 and 1995, the International Commission for the Protection of the Rhine (ICPR) developed and adopted a comprehensive "1998 Action Plan on Floods" covering the period until 2020. In the context of the implementation of the 1998 Flood Action Plan, the flood damage risk (defined as the product of damage potential (€) and the probability of flooding (1/year)) have been assessed. In addition, possibilities for reducing flood levels by implementing measures in the catchment area have been identified. The resulting information was published in the "Rhine Atlas 2001" as one of the elements aiming at increasing the populations "flood awareness". Furthermore, the flood forecasting system has been improved, in particular by improved cooperation between water management administrations and weather services.

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

The implementation of the 1998 Flood Action Plan over the period 1995-2005 was evaluated in 2007. The assessments will be repeated once every 5 years, for the first time over the period 1995-2010.

Adaptation strategy for climate change impacts

A cornerstone of the adaptation strategy will be the ability to forecast possible impacts of climate change on the hydrology of the Rhine (flood levels and durations, low water levels and durations and water temperature). As a first step, an assessment of available information, revealed changes in these parameters over the last 3-4 decades. A second step, the development of common scenarios for these parameters, will be finalised in 2010.

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

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

Source: ICPR secretariat

[10] Switzerland, Germany, France, the Netherlands, Luxemburg, the European Commission.

7 WATER FRAMEWORK DIRECTIVE AND ADAPTATION

7.1 Introduction

7.1.1 Aim and focus of this chapter

This chapter describes guiding principles for adaptation to climate change and relates them to each of the steps in River Basin Management (RBM) under the WFD. Although the guidance is focused on how to respond within the structure of and the timetable for WFD implementation (i.e. up to 2027), the principles proposed would be appropriate for application to other forms of river basin management or for a continuation of river basin management in the longer term.

The WFD RBM steps, which are the focus of this chapter, are:

1. Risk assessment - the summary of significant pressures and impact of human activity on the status of surface water and groundwater (Article 5);
2. Monitoring and assessment of status of surface water (ecological and chemical) and groundwater (chemical and quantitative) (Article 8 and Annex V);
3. Objective setting - under Article 4 for surface waters, groundwater and protected areas, including in particular identification of instances where use has been made of exemptions (Article 4(4), (5), (6) and (7));
4. Economic analysis - a summary of the economic analysis of water use as required by Article 5 and Annex III.
5. Programme of measures to achieve the environmental objectives (Article 11).

Please note: Although public consultation is an important step in the WFD management cycle, it is not specifically addressed in this chapter but it is dealt with in chapter 6. Please also consider the guidance provided in chapter 5 on how river basin managers should handle available information and uncertainty from climate change models, projections and scenarios.

7.1.2 Climate change and the Water Framework Directive

Although the WFD does not explicitly mention risks posed by climate change to the achievement of environmental objectives (see also WFD introduction in chapter 4.1), there is a strong case for incorporating climate change within the RBM process[11]. Furthermore, the underpinning rationale and processes of the WFD are amenable to delivery of adaptation (Figure 1). In particular, the integrated approaches to land, water and ecosystem

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[11] See various sources, such as:

Joint Research Centre, 2005. *Climate Change and the European Water Dimension* – A Report to the European Water Directors. Chapter V. C. Climate Change, of Ecological Status and the Water Framework Directive.

European Environment Agency (EEA), 2007. *Climate change and water adaptation issues*. EEA Technical Report No. 2/2007, Copenhagen, 110pp

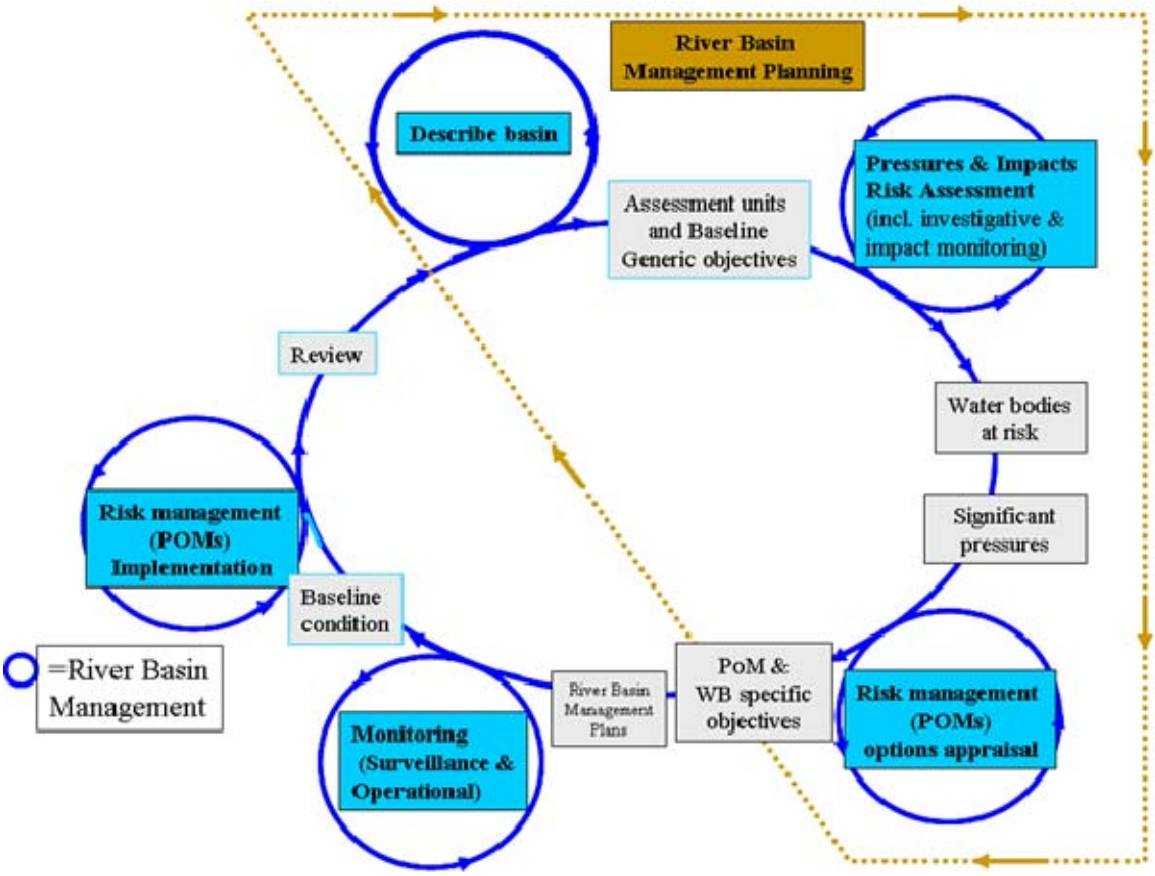
Wilby, R.L., Orr, H.G., Hedger, M., et al. 2006. Risks posed by climate change to delivery of Water Framework Directive objectives. *Environment International*, **32**, 1043-1055

EU Framework VI project Euro-limpacs: http://www.eurolimpacs.ucl.ac.uk/

Wilby, R.L. 2004. Impacts of climate change on reference sites used for ecohydrological restoration and research. *Ecohydrology and Hydrobiology*, **4**, 243-253.

management, combined with the cyclical review of progress, are all consistent with the ideals of adaptive management. Focusing on the resilience of healthy aquatic ecosystems to changing and degrading conditions provide a cost-effective and relatively easy way to achieve adaptation. As the WFD contains several elements that will support the resilience of aquatic ecosystems and the rational use of water resources, achieving its objectives will support adapting to climate change.

Figure 1 Schematic of RBM process and sub-processes under the WFD



Previous work has highlighted the climate sensitivity of:

- Anthropogenic pressures that affect likelihood of achieving good ecological status;
- Monitoring programmes;
- Water body typologies;
- Conditions at reference sites;
- Economic appraisal and cost-effectiveness of investments;
- Effectiveness of programmes of measures in achieving objectives;
- Synergies and conflicts due to mitigation and/or adaptation by other sectors;
- Stakeholder expectations and levels of engagement.

In addition, it should be kept in mind that climate change impacts upstream can have implications for the achievement of WFD objectives downstream, and therefore international cooperation as part of the WFD plays an important role. Please check recommendation of chapter 6 on the need to develop joint and coordinated adaptation strategies in the river basin management of international RBDs.

The guiding principles in this chapter are intended to help those with river basin management responsibilities address each of these sensitivities in a proportionate and robust manner,

whilst acknowledging the inherent uncertainty of regional climate change projections. Where possible, "no-regret" or "win-win" measures are suggested; outcomes should be beneficial, regardless of the eventual nature of climate variability and change. Supporting activities are on-going to provide practical hints related to adaptation strategies, an example of which is the ClimateWater project (http://www.climatewater.org/) briefly described in Annex II.

7.1.3 Which steps in river basin management are most important in adaptation to climate change?

Some of the river basin management (RBM) steps are considered more critical 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
- 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.

Thus, these parts of RBM should be the focus of Member States when considering how to deal with climate change.

It is thus expected that as a minimum, in the 2nd and 3rd cycle of RBM, Member States should clearly demonstrate:

- **how climate change projections have informed assessments of WFD pressures and impacts,**
- **how monitoring programmes are aligned to detect climate change impacts, and**
- **how choices of measures are as far as possible robust to future projected climate conditions.**

Apart from exceptional circumstances, **it is not expected that, within the timeframe of WFD implementation (i.e. up to 2027) and within the metrics used for status assessment, a climate change signal will be statistically distinguishable from the effects of other human pressures at a level requiring reclassification of sites**. It is more likely that indirect pressures arising from human responses to climate change will have a greater impact (such as elevated water abstractions for irrigated agriculture, or new flood defence infrastructure).

However, guidance is provided for cases where sufficient clarity from monitoring evidence shows this is the case. In most cases, climate change may add to existing human pressures and in case these pressures lead to a deterioration of status, this needs to be addressed via the Programme of Measures.

Likewise, climate change should not generally be used as a justification for exemptions, at least in the short term - it is considered that there will be few cases where sufficient scale and certainty in climate projections will combine with a lack of proportionate measures to

require lower than default objectives to be set, but guidance is provided for where this is raised as an issue (see section 7.5). This is applicable to the upcoming RBM cycles.

7.2 Guiding principles for Water Framework Directive and adaptation

The principles set out in the table below provide guidance on how climate change adaptation should be considered in each of the steps of river basin management under the WFD.

Table 1 RBM steps and guiding principles for WFD implementation in a changing climate

RBM steps of WFD	Guiding principle	Summary of the guiding principles for the RBM steps
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	*A more integrated approach to risk assessment is needed to counter changes in pressures that may arise from the direct impacts of climate change, as well as from autonomous and/or anticipatory measures taken by different groups to mitigate and adapt 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.	*Good monitoring networks will be essential to identifying and reacting to climate change and so it is important that sites with long time series of data collection are not dropped from surveillance monitoring. In addition, knowledge of when and where climate change might be first detected could be used to target monitoring and reporting of effects in the most vulnerable water bodies, then to bring forward adaptation interventions as required. This is important for surface water and groundwater (including groundwater quantity monitoring).* *In order to early detect climate change impacts, the monitoring frequency needs to be higher than the WFD minimum for surveillance monitoring, as otherwise it will take a long time to gather robust time series.*
	3 Include reference sites in long term monitoring programmes to understand the extent and causes of natural variability and impact of climate change	*As climate change and human impacts at catchment scale may affect similarly the quality elements used for status assessment, information on coherent changes at reference sites, which by definition are sites with missing or very minor anthropogenic influence, is the primary proof that would enable disentangling the two kinds of impacts. So concurrent hydrometeorological data and data on quality elements are needed to better interpret mid and long-term changes in status.*
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	*There is a danger that anthropogenic climate change could be used as an excuse to set lower objectives for water bodies, even though formal attribution of a detected trend to anthropogenic climate change is unlikely at the scale of RBDs for several decades to come. Although the use of exemptions is an integral part of river basin management planning, applying exemptions without justification in line with the Directive cannot be seen as a general strategy to cope*

		with the consequences of climate change. In addition, there is need to assess the impacts of using exemptions for making water resources more resilient to climate change.
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	*Climate change will mean that the value of water will change as the balance between supply and demand is impacted. Economic analysis carried out in order to apply recovery of costs and judge the most cost-effective combination of measures should consider what these future conditions might be. However uncertainty surrounding projections means that we should look for solutions that will be able to perform over a wide bandwidth of climatic conditions.*
Measures for adaptation related to the WFD		
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	

7.3 Pressure and impact assessment

Guiding principle

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

European freshwaters are already being affected by many human activities, resulting in changes in land-use, pollution with nutrients and hazardous substances, and acid deposition. Healthy, free-flowing rivers respond to changes in land use and climate through dynamic movements and flow adjustments that buffer against impacts. However, many river basins are sufficiently impacted that their ability to absorb disturbances, such as changes in discharge and water stress, is severely limited.[12] Hence management of pressures and the restoration of natural functioning of river basins is an essential part of climate change adaptation.

Member States are required, under Article 5 of the WFD, to carry out a review of the impact of human activity (e.g. point and diffuse source pollution, abstraction) on the status of surface waters and on groundwater (see Annex II of WFD for technical specifications). Climatic change will have an influence on the extent of risk from these pressures. It will be essential not only to understand how the risk from these pressures will change over time without climate change but also to factor in how climate change will add to or reduce the level of risk in order to effectively plan appropriate measures. This will be particularly important where measures are planned that have a long lifespan or limited flexibility (for example large infrastructure projects such as reservoirs or water transfers).

Climate change should be integrated into the processes Member States use for assessing the risks from WFD pressures. As far as possible this should provide a quantitative assessment of the effect of climate change on the risks from pressures using European or Member State climate projection data. For the first cycle of river basin management the influence of climate change on the risks from WFD pressures (and the subsequent effectiveness of measures) may only be qualitative. However, quantitative analysis is needed to establish the severity and timescales over which changes may occur, and thereby improve risk assessments and prioritise adaptation work[13] in ongoing river basin management. More quantitative work is certainly required prior to the implementation of measures which have a long lifespan and are inflexible to later adaptation. Although quantitative analysis may be needed and may take time, certain measures can already be taken, that are likely to make a significant positive impact on the status of a water body: increasing the resilience of the water body is an important no-regret step in adapting to climate change (see section 7.7).

Potentially all of the WFD pressures will be sensitive to climate change. In this context, we need to distinguish between **"primary"** and **"secondary" pressures**. Primary pressures are linked to climatic impacts that affect natural systems or processes (e.g. temperature effects on metabolic rates, less precipitation due to climate change and, therefore, less water flow etc) and/or modify the effects of human pressures (e.g. more frequent flushing of combined sewer outflows). The following table summarises potential primary impacts of climate change

[12] Climate change and the world's river basins: anticipating management options. M A Palmer, C A Reidy Liermann, C Nilsson, M Flörke, J Alcamo, P S Lake, and N Bond. Front Ecol Environ 2008; 6, doi:10.1890/060148

[13] Environment Agency, 2008. *Water for life and livelihoods. Annex H – Adapting to climate change*. Rio House, Bristol, 24pp.

on water bodies. Secondary pressures are understood as pressures due to a human activity adapting to climate change, e.g. increased water storage, leading to a secondary effect of higher concentrations of pollutants downstream.

Table 2 Examples of primary climate change impacts on water status[14]

Parameters	Examples of primary impacts of climate change
Hydrological-hydromorphological	Changing river flows, lake levels and retention times, and sea levels lead to coastal erosion Hydrological connectivity of slopes, channels, and coastal zones Long-term bed-load and channel change Geomorphological processes creating dynamic/diverse habitats Sediment transport changes associated with climate change Changes in groundwater demand and recharge system induced or enhanced by climate change
Physico-chemical	Changes in water temperature and dissolved oxygen Decreased dilution capacity of receiving waters Increased erosion and diffuse pollution More frequent flushing of combined sewer outflows Potential remobilisation of sediment- and soil-associated historic contamination Photoactivation of toxicants Exceedence of water quality standards Salt water intrusion (both into groundwater and upstream into estuaries and tidal river systems)
Biological-ecological	Changing metabolic rates of organisms Changing ecosystem productivity and biodiversity Climate space of plant and animal distributions Fish migration patterns and dispersal corridors Increased eutrophication and occurrence of algal blooms Changes in aquatic fauna and flora including those at reference sites Changes in species assemblages in designated areas More rapid decline in faecal indicator organisms and pathogen populations Increased microbiological activity Decreasing groundwater levels may have adverse

[14] Taken from Wilby, R.L., Orr, H.G., Hedger, M., et al. 2006. Risks posed by climate change to delivery of Water Framework Directive objectives. *Environmental International*, **32**, 1043-1055.

	effects on depending terrestrial ecosystems

Note: Impacts may be considered at three levels: i) Hydrological/hydromorphological, ii) physico-chemical, and iii) biological-ecological. The power to attribute these impacts directly to climate change fades in the same order and will forever remain very weak at the biological level.

Management actions taken to address one pressure (or combinations of pressures) may increase the risks of not achieving WFD objectives for other pressures. Likewise, measures taken to mitigate emissions of greenhouse gases or to adapt to unavoidable climate change could indirectly affect or introduce new pressures to water bodies. Some actions may lessen pressures; others may increase pressures (as with greater water demand for bio-fuel production). **It is likely that such secondary pressures (i.e. pressures from human uses of water adapting to climate change) will have the biggest effect on water status on the short-term.** The following table lists possible secondary climate change impacts and effects on water quality.

Table 3 Examples of secondary climate change impacts and effects on water quality

Secondary climate change impacts	Effects
Reduced nitrogen emissions to air	Smaller area of acidic deposition and area of ecosystems adversely affected by excessive nitrogen (eutrophication)
Increased bio-fuel production	Increased groundwater acidification caused by enhanced acid deposition to forestry and removal of soil cations during harvesting; impacts on ground and surface water quality through increased fertilizer and pesticide use as well as more intensive agricultural practices on currently set-aside or extensively used agricultural land
Increased water supply and storage	River regulation and inter-basin transfers change thermal and chemical composition of downstream waters. Dams modify river habitats and hamper fish migration. In case of increased water recycling, higher concentrations of persistent pollutants due to water re-use
Increased hydropower production	Changes in environmental flow of regulated rivers (secondary impacts from the Renewables Directive like proposals for new hydropower development and increased use of hydropeaking) Hydropower is an important renewable energy opportunity, but may impact on the achievement of good ecological status through changing flow patterns and modifying channel structures. Hydropower guidance should be followed to minimise these risks.
Longer growing seasons	Changing cropping patterns, increased agricultural pesticide and fertilizer use cause negative impacts on water quality; changes in soil tillage; diffuse runoff quality; increased water demand for irrigation; increased vegetation cutting and weed clearance in navigable water bodies
Changing fire management regime	Controlled burns in headwaters; contamination of groundwater resources; increased export of organic carbon, sediments and toxics
Measures to reduce flood risk	Improved urban water quality thanks to sustainable urban drainage systems, or upgrading of sewerage systems to cope with higher rainfall intensity; increased saline intrusion due to managed retreat of coastal defences
Removal of obstacles to assist movement	Increased risk of spread of invasive species

Risk assessments that are too narrowly focused on existing pressures within river basins may overlook important, but often remote or indirect, drivers of change. This underlines the need for a more integrated approach to river basin management and for engagement with a much broader constituency of stakeholders and planning processes (e.g. development planning, flood risk management planning). In many respects, indirect influences on pressures could be invoked (and therefore impact water body status) earlier than direct climate change impacts projected from, for example, higher temperatures or lower rainfall.

In general, however, this Guidance Document does not intend to summarise the large quantity of research evidence that is emerging and continuing to develop on the subject of climate change impacts on the water environment. It is recommended that those with responsibilities in river basin management familiarise themselves with the main sources of this information and keep up to date with relevant findings as they develop, in order to determine the likely impacts in their river basins. The findings of JRC and EEA, together with Member States own research institutions as well as results of key European projects (see Annex II of this Guidance) should be consulted.

Suggested actions

- Consult the findings of key research institutes (such as the EEA, JRC and national institutes (e.g. UK Climate Impacts Programme)) and of national and EU-funded research projects to develop your understanding of the potential climate change impacts on the water environment in your country or river basin.
- Identify direct climate change impacts on the risk from WFD pressures and, where possible, integrate into existing approaches for the quantitative risk assessment of pressures.
- Identify pressures that could be indirectly affected by climate change mitigation or adaptation policies considering also developments in other sectors, using expert opinion, local knowledge, literature reviews or targeted research.
- Estimate the time-scale(s) over which direct and indirect climate change factors might influence pressures on water bodies. Include consideration of longer term timescales (up to 2050 at the minimum) in order to understand and plan for longer term challenges.
- Report on how these pressures could influence achievement of WFD objectives and identify corresponding measures.

Example 7a – Direct climate change impacts on river water quality

An appraisal is undertaken to determine the potential impact of climate change on the water quality of rivers receiving consented discharges from sewage treatment works (STWs). Projected changes in monthly river flows for the 2020s are used to calculate final concentrations of phosphate, ammonia and dissolved oxygen via a simple mixing model applied to river reaches. The effects of water temperature on rates of reaction in rivers and on the solubility of dissolved oxygen, as well as effects on the flow and quality of discharges from STWs are also taken into account. The model then calculates the length of river falling into each of the five classes used for the WFD.

The modelling suggests only a small percentage of rivers should be downgraded when comparing river lengths in each water quality class in the 2020s with those in 2000. The reductions are due mainly to reduced dilution of current discharges from sewage treatment works, manifested by less

desirable concentrations of phosphate and dissolved oxygen. Assuming the permanent loss of the river lengths downgraded from Good Status, the cost of the climate impacts can then be expressed as a Net Present Value. These damages can be weighed against the costs associated with programmes of measures to reduce pressures, such as more stringent consents for point discharges from STWs.

Example 7b – Decrease of the river flows within the Adour Garonne basin, France

Climate projections made by Météo France show that river flows could decrease by 25% as an annual average by 2050, for the entire Adour Garonne (AG) district. This decrease of the flows could reach 36% during spring and summer. The water status could be largely influenced, due to the combination of higher temperatures and decrease of the river flows. At the same time risks from anthropogenic pressures could increase. For example, projections by the "Statistics project for the population of AG district" showed a population increase of up to 20% by 2030. This could increase the conflict between water uses and users. New measures will be necessary to mitigate these effects and integrate climate change constraints.

Example 7c – Salmon already in "hot water"

Climate projections suggest most rapid warming in southern and eastern parts of the UK. The same regions are also expected to witness the earliest signs of depressed groundwater flows in summer. Indeed, rising air and water temperatures are already beginning to affect salmon distributions through changes in behaviour and physiological harm at different life-cycle stages. Synergistic effects of drought, over-abstraction, low dissolved oxygen concentrations, and higher salinity further reduce thermal tolerances of fish in estuaries.

Under the present conditions there is on average only one day per summer when water temperatures would deter migration upstream, but approximately one week during which conditions in the tidal river delay migration. As summer air temperatures increase the window of opportunity for fish to pass through the estuary becomes narrower, and hence the loss of fish rises. Without interventions, the viability of the salmon population is threatened in some "Low, Small/Medium Calcareous" rivers within a few decades.

Example 7d – Development of a numerical model in a transboundary aquifer

One of the objectives of the Scaldwin[15] project is the study and management of two transboundary groundwater layers or aquifers: the carboniferous limestone aquifer (shared between France and Belgium), which suffers from overexploitation, and the groundwater in the Dutch-Flemish polder area, which suffers from saltwater intrusion. The carboniferous limestone aquifer has a high economic value as a drinking water resource. The possible salinization in the Dutch-Flemish polder area will have a negative impact on the agricultural activities. For the latter, a joint numerical groundwater model will be developed, which will allow to us to gain an insight into the future distribution of fresh and saltwater under influence of climate change and sea level rise.

Example 7e – Increasing nitrogen loading in Southern Finland

[15] http://www.nweurope.eu/index.php?act=project_detail&id=3871

A set of climate change scenarios suggest an increase of 2.8–4.7 ºC in annual mean temperature and 10.1–23.6 % increase in annual precipitation in southern Finland for period 2070–2100. The considerable increase in winter (December-February) temperatures (3.4–6.2 °C) and precipitation (26–56 %) predicted by the different scenarios influence strongly the hydrological regime, especially snow accumulation and snow melt in spring. According to model results such changes would increase the annual inorganic N load from catchments by 10–70 %. This is due to higher mineralization rate and increased water flow through the catchment soils. The predicted changes are more pronounced in an agricultural lowland catchment than in the forested one, particularly during the dormant period, from November to February. Efficient catchment scale mitigation measures are needed, especially on the agricultural sector, to prevent eutrophication of surface waters in future climate conditions.

Example 7f – River flow modelling in the Blsanka river basin, Czech Republic

Several rivers are located in a low precipitation region in the Czech Republic and their hydrological conditions have deteriorated during the last two decades, which are probably already affected by impacts of initial stages of climate change. The main problems occur during drought periods, when river discharges drop below minimum ecological flows, the river water is excessively polluted by waste water discharges from urban areas and the water resources are insufficient for meeting water use requirements for the purposes of agriculture, which is very important economic sector in this region.

In order to make decisions about effective measures, it was necessary to derive volumes of water, which are missing during drought events (deficit volumes) to ensure effective dilution of waste water and for maintaining the required ecological flows to keep the ecological function of the stream. Results of the application of deficit volume method (Tallaksen & Lannen, 2004) by using the EXDEV computer program showed that the storage capacity for ensuring ecological flows during the period 1969 – 2008 would be 510 megalitres (deficit in 2007). Including scenarios for climate change in the model suggests that the deficit volume will increase in range from 3260 megalitres (according to scenario RCAO B2) to 5750 megalitres (scenario HIRHAM A2) until the year 2085.

7.4 Monitoring and status assessment

Guiding principles

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 the impact of climate change

7.4.1 General remarks

Implementation of the WFD is based on objective and transparent criteria and procedures as agreed in the Common Implementation Strategy, e.g. for defining surface water body types, reference conditions, and quality class boundaries. Furthermore, it is based on robust monitoring data. Although climate change has the potential to impact on virtually all quality

elements included in the definition of WFD ecological status, this does not affect the principles of water status assessment, which remain valid.

There is some evidence that anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents[16]. However, apart from exceptional circumstances, **it is not expected that, within the timeframe of WFD implementation (i.e. up to 2027) and within the metrics used for status assessment, a climate change signal will be statistically distinguishable from the effects of other human pressures at a level requiring reclassification of sites**.

In only few cases, climate change could impact status assessment in the relatively short term and influence the water body type and/or reference conditions. It is more likely that climate variability and change will work alongside pressures from human activities, which have to be addressed with measures to achieve good status. However, some general principles on how to deal with climate change induced changes, if they occur, are given below.

In the future, there will be certain areas in Europe that will be the first to clearly identify climate change impacts requiring an assessment whether additional measures need to be taken to achieve good status. There are now a number of cases where tentative links to climate change are claimed (see examples below). It is essential that in these cases, sufficient monitoring is taking place that is linked to meteorological monitoring, and that both have a long enough time series reaching at least 20 years to avoid over-interpretation of any short term observed trends.

7.4.2 Monitoring

Monitoring will be essential to understanding and appropriately responding to climate change across Europe. After all, an appropriate river basin management response to climate change impacts can only be based on a **sufficiently robust long-term monitoring network of reference sites linked to meteorological data**. Otherwise, one may run the risk that designed measures may not tackle the real pressure.

Whilst monitoring programmes under the WFD are generally not designed for the need to identify and monitor climate impacts, all long-term monitoring programmes will inherently contribute to the detection and understanding of any climate change signals. It is very important to take a consistent and long term approach. Monitoring programs should be planned carefully with a long-term perspective and carried out consistently preventing major changes in the station network or methodologies such that comparisons can be made between years (this is the basic idea of any surveillance monitoring). It is very important to avoid abandoning monitoring stations which already have a long term consistent record, especially in the context of climate change. Notwithstanding the above, it may be possible when designing monitoring programmes to target reference sites (see 7.4.4) or "hot spots" of predicted climate change impact when adding new stations.

As a first approximation, climate change is expected to "squeeze" climate space occupied by high-elevation and coastal-zone ecosystems[17]. The former are already experiencing reduced snow/ice storage and amplification of extreme rainfall events; the latter rising sea levels and ocean temperatures. Other climate change impacts will be manifested through changes in

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[16] Cynthia Rosenzweig et al., Attributing physical and biological impacts to anthropogenic climate change, Nature, Vol 453| 15 May 2008

[17] Walmsley, C.A., Smithers, R.J., Berry, P.M., Harley, M., Stevenson, M.J. and Catchpole, R. (Eds.) 2007. *MONARCH – Modelling Natural Resource Responses to Climate Change – a synthesis for biodiversity conservation*. UKCIP, Oxford, 100pp.

disturbance regimes involving fire, pests, disease and competition from invasive species. These drivers will interact with existing pressures such as pollution, exploitation of natural resources, or land-cover change. Therefore, the resulting climate change "hot spots" might be regarded as a composite of the climate projection, distribution of existing pressures, and underlying pattern of vulnerable habitats and species.

Knowledge of *when* and *where* climate change might be first detected could be used to target monitoring, conservation efforts and resources[18,19]. Until now, attributable human-induced climate change impacts have occurred in air and water temperature dependent responses (such as timing/volume of snowmelt, species' distribution and phenology)[20]. The risk of extreme heat-waves has already increased[21]; detectable changes in heavy precipitation could emerge by the third cycle of RBM under the WFD[6]. Where there are no economically or technically feasible means of countering such trends and their biological impacts, reducing other pressures to "buy time" may be the only rational option.

Please refer also to chapter 6 for further guiding principles on data collection to improve decision-making in river basin management under climate change as well as chapter 9.3 on monitoring for detecting climate change impacts on quantitative elements of water resources.

Suggested actions

- Do not systematically redesign monitoring programmes around climate change but, as part of general good practice, plan monitoring programmes carefully to take a long-term perspective, and apply consistently without changing the station network or methodologies. Do not abandon stations which already have a long-term consistent record.
- Notwithstanding the above:
- Where possible establish more intensive monitoring of vulnerable water bodies to better understand the pace and mechanisms of change, and use these sites as sentinels of climate change. In cases where the minimum WFD monitoring frequency is applied, assess whether this is sufficient; in order to early detect climate change impacts, the monitoring frequency needs to be higher than the WFD minimum for surveillance monitoring, as otherwise it will take a long time to gather robust time series.
- Encourage a monitoring programme that includes long-term, concurrent meteorological, water quality and biological monitoring of reference sites to improve evidence of causative links between climate variability and local ecological status.
- Compile register of species-dependent hydro-climatic thresholds and damage functions. Intensify monitoring of most vulnerable species/ecosystems to better understand the pace and mechanisms of change, and use indicator species to track impacts with/without adaptation.

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[18] Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**, 853-858.

[19] Scholze, M., Knorr, W., Arnell, N.W. and Prentice, I.C. 2006. A climate change risk analysis for world ecosystems. *Proceedings of the National Academy of Sciences of the United States of America*, **103**, 13116-13120.

[20] See e.g. EU research projects Euro-limpacs and CLIME

[21] Stott, P.A., Stone, D.A. and Allen, M.R. 2004. Human contribution to the European heatwave of 2003. *Nature*, **432**, 610-614.

Example 7g – Additional monitoring needed for detecting climate change induced changes to salt marshes

The salt marshes of the Dutch, German and Danish Wadden Sea, and the marshes of the British East Coast (classified as type K2 – polyhaline sheltered coastal waters) are highly dynamic and natural ecosystems with tidal channels, sands, mud flats, salt marshes, beaches, dunes and a transition zone to the North Sea. They form the upper parts of the intertidal zone and are the interface between mainland (the embankments) and the sea. Besides being highly valuable habitats, foreland marshes give a self-regulating protection of the embankments for coastal flood defence. The presence of a salt marsh in front of a seawall will thus improve safety of the hinterland and reduce the cost involved in seawall maintenance.

The Dutch have shown that the elevation of their foreland marshes is currently able keep pace with current 2.5 mm/yr rise in sea level. The threshold value for the intertidal flats seems to be a (relative) sea level rise of 6.0 mm/yr. Beyond this threshold intertidal flats start to disappear and even protection from erosion (e.g. by brushwood groynes) will no longer be sufficient. Although salt marshes may receive sufficient sediment to compensate for (relative) sea-level rise, lateral erosion of the salt-marsh edge can result in a net loss of salt-marsh area. A poor vegetation cover in the pioneer zone in front of the marsh can provide less protection of new sediment, with a subsequently lower net sedimentation. The effect leads to cliff erosion. This erosion can be intensified by strong winds, high tides and increased wave height, which in turn may be caused by climate change and human activities like land claim, dredging and canalization.

Because of possible climate change-induced large-scale effects it is important to use trilaterally (Denmark, Germany, Netherlands) harmonized criteria for monitoring the salt marshes. The following parameters are monitored every five years trilaterally: location and area, vegetation types, land use/management, geomorphology and drainage. Changes in geomorphology by climate change will take at least decades to happen. But once a threshold has surpassed after for instance a few decades, rapid changes in the vegetation cover can occur. It is likely that the common (WFD) monitoring will be sufficient to detect climate change-induced changes at the physical level (i.e. area of salt marsh and the relative soil levee), but additional monitoring may be required in order to establish the relation between ecological changes and climate change.

7.4.3 Surface water body types

Water bodies are "typed" by a set of obligatory (e.g., topographic, geological, physical, hydrological) and optional (e.g., water depth, mixing characteristic, nutrient status) descriptors. A number of these descriptors are climate sensitive. As any typology is a simplification compared to the natural continuum, some water bodies always remain on type boundaries and could, in theory, migrate from one type to another as a consequence of gradual climate change or sequence of extreme events. Over longer time horizons there is even the prospect that some sites could shift between different categories of water bodies, such as a lake to transitional water category. Any refresh of characterisations would have to be mindful of the fact that natural climate variability could result in temporary migrations between types. So there is an open question surrounding the length of the sampling period needed to confidently re-assign a water body from one type to another.

In order to keep the number of water bodies with ambiguous types at the minimum, typologies should be created as close as possible to the naturally occurring patterns using, e.g. clustering or other multivariate techniques. If the type of some water bodies will still change as a result of CC, these water bodies should be transferred to the appropriate type and the corresponding reference conditions applied to them.

Ecosystems of some types of water bodies, e.g. large shallow lakes, are more physically controlled and thus more sensitive to climate change.

Suggested actions

- Undertake a risk assessment to determine the extent to which climate change could trigger transitions between categories and types within rivers, lakes, transitional, coastal and artificial water bodies.
- Where possible establish more intensive monitoring of vulnerable water bodies to better understand the pace and mechanisms of change, and use these sites as sentinels of climate change.

Example 7h – Change of water body type

A low-lying, near coastal lake was initially typed as "High alkalinity, Very shallow" because the $CaCO_3$ concentration is more than 50 mg/l, and the mean water body depth is less than 3 m. Certain objectives (and standards) apply to this type which help define its management.

According to the UKCP09 scenarios (http://ukclimateprojections.defra.gov.uk), between 61 and 87 mm of relative sea level rise is expected over the next 20 years (for high and low emissions scenarios respectively).Consequently, in this hypothetical case, after a series of stormy winters nearby coastal defences and dykes are permanently breached and sea water periodically enters the lake under very high tides. The morphology of the lake is unchanged but the water is now brackish. In the absence of new coastal defences, the site is now characterised as "Brackish, Very Shallow". Objectives and management may have to shift to suit this new type of lake.

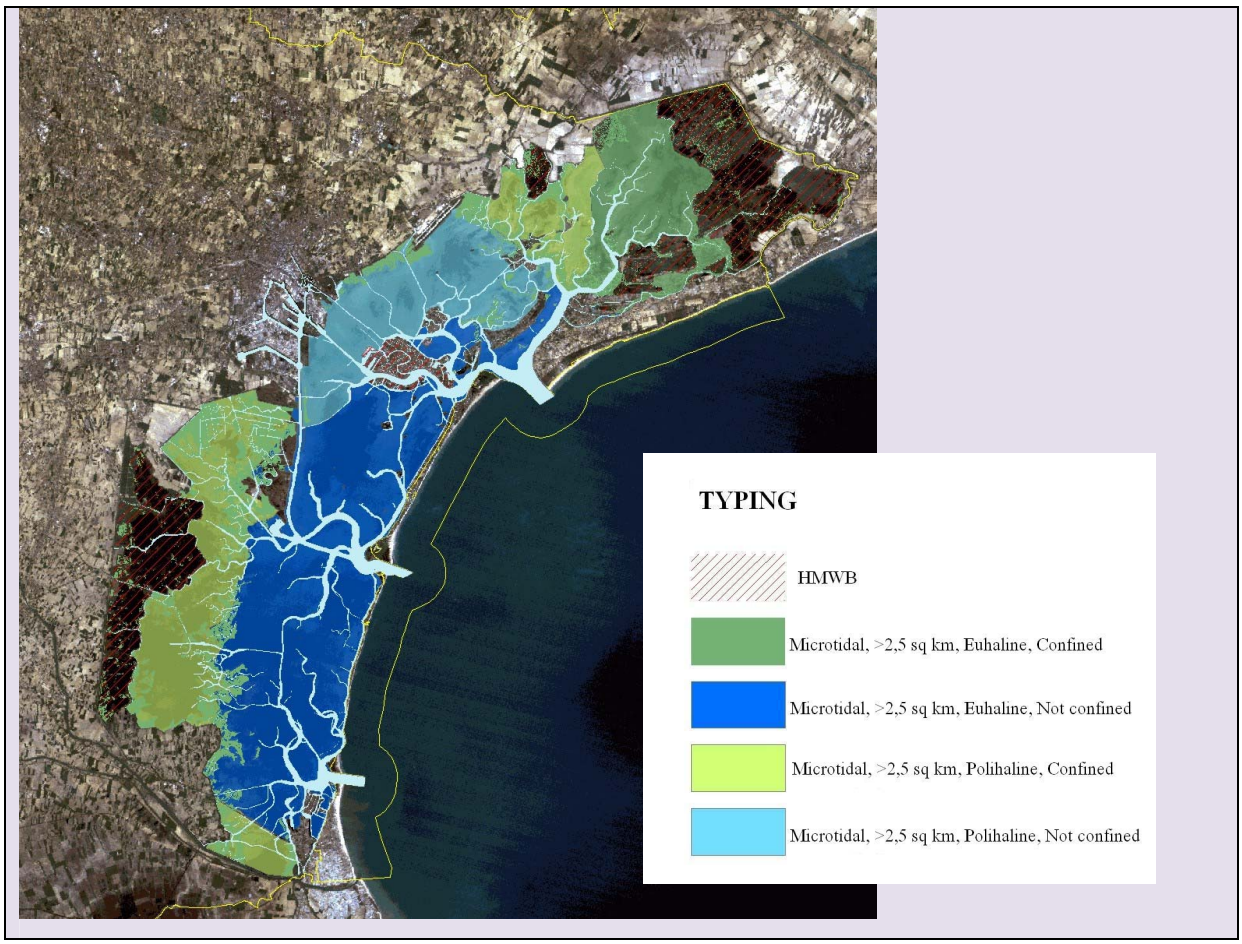
After a few more decades of net sea level rise, and near permanent connection to the sea, the water body is characterised as a "Transitional lagoon". Once again, objectives and management may have to shift to suit the new conditions.

Example 7i – transitional water in Mediterranean Ecoregion: the Venice lagoon (Italy)

Physical descriptors used for transitional water types in Italy are annual average salinity and tide range (the other descriptors are optional, such as the degree of confinement). In the Adriatic sea, three possible effects of climate change can be considered: rising mean sea level, increasing sea temperatures, and "tropicalisation" of temperatures and rainfall.

Tides and Sea level: The Venice lagoon is micro-tidal and it is not likely that the projected sea level rise will be more than 2 m (current tide range is around 1 m): therefore, there are not likely to be no migrations to a meso-tidal lagoon type.. Furthermore, in the Mediterranean Ecoregion depth is not a descriptor for the transitional water typology, therefore any changes in the sea level will not cause any direct migration between types.

Salinity, sea level and rainfall: changes in salinity can be caused by an increasing sea level or by an increasing/decreasing rainfall. Venice lagoon (fig. 1) is now polihaline around the edge (salinity: 20-30 psu) and euhaline close to the inlets (salinity: 30-40 psu) and the observed trend shows a marinisation process within the lagoon. The projected increase in sea level could increase this process and the polihaline areas could shift to euhaline type. A reduction in mean rainfall over the basin could reduce fresh water inflows to the lagoon and cause the same migration between types. Conversely, increasing rainfall and fresh water inflows can favour migration toward polihaline types, despite the current marinisation process.



7.4.4 Reference sites

The objectives of the WFD include that water bodies should not deteriorate and that they should achieve "good status" by 2015[22]. For surface waters, "good ecological status" (or "good ecological potential" in the case of heavily modified and artificial water bodies) is defined by reference conditions for different water body types. Reference conditions should be set based on objective criteria, preferably by measuring ecological status in unimpacted sites (with agreed pressure criteria for what is unimpacted). Monitoring of reference sites will be essential to understanding and appropriately responding to climate change across Europe (see also section 7.4.2). In fact, a **sufficiently robust long-term monitoring network of reference sites, i.e. sites with missing or very minor anthropogenic impact, linked to meteorological data** will be the only direct way of detecting responses of water bodies to climate change impacts. Only if such monitoring reveals long term coherent changes in the status of reference water bodies over large geographical areas, it will be a proof of changing reference conditions. In practice, as the intercalibration exercise showed, MS use slightly different criteria for selecting reference sites. Use of best available sites instead of real reference sites should be marked as such and defined as an alternative benchmark (e.g. good status).[23] If the conditions at reference sites change, it will be really important to find

[22] Good chemical and ecological status for surface water bodies; good chemical and quantitative status for groundwater bodies.

[23] The procedure on how to define alternative benchmarks is described in CIS Guidance Document No. 14: Guidance on the Intercalibration Process 2008-2011.

out the causes and decide whether the site can still be used as a reference site or not. Such a decision should be supported by results of a sufficiently robust long-term monitoring network linked to meteorological data, including a demonstration of the specific impact of climate change.

Unless biological systems are already close to thermally and hydrologically induced "tipping points"[24], climate trends are expected to play a minor role in early WFD river basin management cycles; natural variability in annual and seasonal climate will be far more significant. Therefore, status definitions should be sufficiently wide ranging to accommodate natural variations within types. Given the brevity of many monitoring programmes, short-term trends in ecological status should be interpreted with extreme caution.

In general, reference conditions and default objectives should not be changed due to climate change projections over the timescales of initial WFD implementation (up to 2027) unless there is overwhelming evidence to do so.

Where there is judged to be significant risk that climate change (and possibly having regard for climate change related policy) would lead to failure to achieve the objectives set for 2015, 2021, 2027 or beyond, this should be noted in the river basin management plan since it is relevant information to the plan user and may assist in considerations of optimization of scarce resource use between locations and objectives earlier in the plan than when non-compliance projected to occur.

For the upcoming WFD cycles, the following actions are suggested in case monitoring data show strong evidence that conditions at reference sites are changing:

Suggested actions

- In order to achieve better distinction between climate change pressures and other human pressures, maintain robust long-term, concurrent meteorological, water quality and biological monitoring to improve evidence of causative links between climate variability and local ecological status. Maintain monitoring programmes at sites with a long history of monitoring in order to give the longest possible time series.
- Use homogeneous climate indices (for instance the NAO, Central England Temperatures or England and Wales Precipitation series) to contextualise biological samples taken under different conditions (i.e., hot-dry, cool-wet, etc). Use paleo-environmental reconstructions and other proxy evidence to represent the full range of conditions experienced at reference sites over multiple decades.
- Undertake periodic reviews of conditions and pressures at reference sites to assess whether the site can still be used as a reference site.
- Prioritise to distinguish climate change impacts from those caused by other anthropogenic pressures.
- Be aware of the challenges associated with attribution of environmental changes to anthropogenic climate change and avoid over-interpretation of observed trends.
- Focus on how climate variability and change will work alongside pressures from

[24] For example, increasing water temperatures combined with lower flows in summer could have lethal and non-lethal impacts on aquatic species such as salmon. See: Solomon, D.J. 2008. *The thermal biology of brown trout and Atlantic salmon: A literature review*. Environment Agency Southwest Region, 40pp.

human activities and use the degraded water status because of these various pressures as the starting point for planning of measures.

Example 7j – Understanding biological changes[25]

Macro-invertebrate data for an upland region show declines in species diversity, inter-annual stability, and abundance since the 1980s at circumneutral (but to a lesser extent at acidic forest or moorland) sites. The declining biodiversity appears to coincide with reduced atmospheric deposition of acidifying substances, and rising stream pH at all sites. In other words, decades of industrial regulation and pollution control do not appear to have yielded intended environmental outcomes.

Further analyses of the macro-invertebrate data reveal strong correlations with winter air temperatures and the North Atlantic Oscillation (NAO) index. A long-term trend towards more positive phases of the NAO (typified by warmer wetter winters and increased runoff) since the 1960s is associated with lower abundance of macro-invertebrates in spring. It is too early to say whether such behaviour in the NAO is a manifestation of human-induced climate change. However, the data show the extent to which the "bandwidth" of invertebrate abundance can vary from year to year and decade to decade. The data further imply declining abundance (ignoring in-migration) under warmer future conditions. This example would justify further monitoring.

Example 7k – Impacts on fish distribution and abundance in the Baltic Sea

Changes in marine species observed in the Baltic Sea do not fit into the general pattern of northward shift due to increasing temperature. In this sea, salinity is one of the predominant factors that influence species presence. Salinity ranges from high (close to oceanic values) at the boundary of the North Sea to almost fresh water in the Bothnian Bay (northernmost part between Sweden and Finland). In general, the Baltic aquatic ecosystems are dominated by marine species in the western parts near the North Sea boundary, with predominantly brackish and freshwater species in the central parts. A small change in salinity could change the distribution of species. Changes in salinity are driven by climate-induced changes in precipitation and salt water inflow from the North Sea. It appears that changes have already been large enough to affect the composition of the Baltic Sea biota.[26]

Salinity in the Baltic has decreased steadily since the mid 1980s due to increased freshwater input (precipitation) and a reduction in the frequency of inflow events from the North Sea, which bring in more saline, oxygenated water. Projections for the future climate of the Baltic are for continuing increases in precipitation and decreases in inflows from the North Sea, therefore the distribution and abundance of cod and other marine species is likely to continue to diminish. Their position in the ecosystem may be taken over by more brackish and freshwater species, such as whitefish, pikeperch and perch[27].

Example 7l – Divergence in comparability to reference site for Lake Ijsselmeer

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[25] Durance, I. and Ormerod, S. 2006. Climate change effects on upland stream invertebrates over a 25 year period. *Global Change Biology*, **13**, 942-957.

[26] A general description of effects caused by climate change are available at: Swedish Environmental Protection Agency (2005). Changes Beneath the Surface, Monitor 19. An In-Depth Look at Sweden's Marine Environment. 192 p. ISBN: 91-620-1246-0.

[27] MacKenzie et al., 2007 as cited in EEA Report No 4/2008 Impacts of Europe's changing climate - 2008 indicator-based assessment.

1. Characterisation: Lake Ijsselmeer is a large (114.000 ha), shallow lake (av. 4,6 m) in open connection with Lake Ketelmeer (3200 ha, 3,6 m) and Lake Zwarte Meer (1800 ha, 1,8 m). Lake Ijsselmeer was classified as M21 (large lakes > 10,000 ha, > 3 m depth, even though it is not stratified), the others as M14 (<10,000 ha, < 3 m depth). Due to sea-level rise, the fixed water-levels used in the lakes at present will have to be raised in future, with a maximum raise of 1,5 m. This will change the average depth and the chances of stratification-like conditions occurring.

2. Reference conditions: The water level rise proposed changes the lakes to such an extent that the present reference lakes may become no longer applicable. Lake Peipsi in Estonia/Russia, is currently used as a reference site for Lake Ijsselmeer, however it is shallower and its discharge is not affected by sea-level rise because of the postglacial uplift (rebound) in its part of Europe. The change in water levels and stratification will be monitored to allow a change in reference site to take place if it is shown to become necessary in due course.

Example 7m – Impacts on biodiversity in the Adour Garonne River Basin, France

The following study is a study from "Groupement d'Experts Intergouvernementaux sur l'Evolution du Climat" (GIEC) this study was done by Cemagref (Eric Rochard 2008), which is an international body of research specialists of climate change. The Study realised for the Adour Garonne River basin is part of an overall study on impact of climate change over 200 European river basins. This study is providing reference conditions starting in 1900. The study shows that the major impacts of climate change on rivers and fish species are expected in the middle and long term. Models propose 4 scenarios till 2100. The study clearly highlights already existing impacts of climate change starting from the reference date 1900.

One case study demonstrates that the temperature of water has increased by 1°C over the last 20 years on the Garonne Estuary, due to climate change and associated events such as heat waves and droughts. The increase of the temperature has been monitored over a long period of time about 20 years. At the same time there was no increase of anthropegenic pressures (no additional abstractions, discharges,….) in the same area. This increase of temperature has contributed to the disappearance of the fish "eperlan" in the estuary of the Garonne river and of the "Flet" the have been replaced by "anchois" due to the decrease of fresh water in the Estuary.

At the same time, a lot of invasive species (fauna and flora) are appearing in the Adour Garonne district, such as the "Bull frog", the "ecrevisse de Louisianne", the myrophilla from Brazil. All these species are modifying the biodiversity by the disappearing of local species (Eperlan, anchois,…) and the appearance of these invasive species. The quality indicator based on the endemic fishes and invertebrate species for the Garonne river will be modified in the years to come. The invasive species less valuable from an ecological point of view contribute to a diminishing biodiversity and at the same time have an impact on some parameters of GES (Fishes, invertebrates). A decrease of the biomass has also been identified by the CEMAGREF study.

The changes in species of fishes in invertebrate will have to be monitored carefully in the years to come in order to see if it could have an impact on the reference conditions of the Garonne river.

These impacts on biodiversity, GES and reference conditions are mainly due to the increase of the temperatures for the entire Garonne river and of the salinity in the Estuary and its progression up stream. Models driven by data starting in 1900 already show the impacts of climate change on the river basin which are expected to increase exponentially till 2100. At the same time the increase of the salinity combined with the ground water depletion is a factor of deterioration of the ecological status of the Garonne aquifer linked to the river. The salt intrusion is having an effect of the ecological status of this aquifer.

Reference GIEC's study CEMAGREF 2008 case study of Adour Garonne river basin

7.5 Objectives setting

Guiding principle

4. Avoid using climate change as a general justification for relaxing objectives, but follow the conditions set out in the WFD

Article 4 of the WFD expects Member States to achieve good surface water status and good groundwater status at the latest 15 years from the date of entry into force of the WFD, but provides for the possibility for exemptions to this rule. Paragraph 5 of Article 4 allows Member States to achieve less stringent standards where achievement of these objectives would be infeasible or disproportionately expensive. Paragraph 6 of Article 4 allows for temporary deterioration in the status of bodies of water only in circumstances where the extreme event is "exceptional or could not reasonably have been foreseen". Paragraph 7 of Article 4 allows for new modifications to the physical characteristics of water bodies leading to status deterioration under certain conditions.

Climate change has the potential to impact on the feasibility or expense of achievement of objectives. The EU Water Directors have endorsed that, whilst the use of exemptions is an integral part of river basin management under the WFD, exemptions without justification in line with the Directive cannot be seen as a general strategy to cope with the consequences of climate change. At the same time, the use of exemptions can have negative consequences for making water resources more resilient to climate change impacts.

Whilst it is expected from projections that there may at some point be unavoidable changes to water status due to climate change, there is still significant uncertainty (particularly relating to climate models) over the timing and nature of these changes. Largely it will still be difficult to distinguish the climate change signal from natural variability or other human impacts over the timeframe of the WFD (up to 2027). It is thus necessary to base decisions on the basis of clear monitoring evidence (see principle 2), and not to proactively aim for less stringent objectives based on modelled assumptions of future climate.

However, there may be cases where there is sufficient evidence that the expected scale of climate change impacts on pressures is large enough that the measures needed to meet default objectives would be too expensive or technically infeasible. Where climate change is brought forward as the underlying reason for exemption due to excessive cost or unfeasibility, a clear and robust evidence base as for exemptions in other cases and consistent with other aspects of the approach to climate change should be provided. Within this evidence, DETECTION of a trend alone will be insufficient to invoke a change of policy and process, and ATTRIBUTION of the trend to anthropogenic climate change will be required. Detail on the process and difficulties associated with attribution of changes to anthropogenic climate change are provided in the literature[28]. Put simply, for positive attribution to take place, the observed data should sit outside the range of natural climate variability and be inexplicable other than through the impact of anthropogenic climate change.

The evidence base should also be clear about the inherent uncertainty in climate projections and include consideration of costs and benefits over a range of timescales and potential

[28] Hegerl, G.C., Karl, T.R., Allen, M., Bindoff, N.L., Gillett, N., Karoly, D., Zhang, X.B. and Zwiers, F. 2006. Climate change detection and attribution: Beyond mean temperature signals. *Journal of Climate*, **19**, 5058-5077.

climatic futures. The full range of potential measures and combinations of measures should be considered.

The process for assessing the need for less stringent environmental objectives should therefore link closely with the economic analysis of measures. Guidance on including adaptation to climate change in economic analysis is given below in section 7.6.

In addition, as extreme events, such as droughts, floods and surge tides may occur more frequently under a changing climate, robust scientific evidence should determine on a case-by-case basis whether they can be considered as exceptional or that they cannot reasonably be foreseen, as referred to in Article 4(6) of the WFD (see also relevant discussion on "exceptional floods" in chapter 8) and prolonged droughts in chapter 9.2.

Finally, the implementation of specific adaptation measures, for instance infrastructure projects, might invoke exemptions according to Article 4(7) of the WFD more often. As explained in section 7.7, certain adaptation measures to climate change can be counterproductive to WFD aims, e.g. storage basins. Such measures need to meet the conditions set in Article 4.7 of the WFD on new modifications (see CIS WFD policy paper on Article 4.7 exemptions).

Suggested actions

- Manage the expectations of stakeholders in terms of how significant an impact climate change will be in the timescale of the WFD.
- Closely monitor and at each cycle review characterisation for any specific water bodies for which lower than default objectives were considered due to climate change.
- When considering impacts of climate change as a basis for justifying exemptions, first establish climate change as the most probable cause of any observed changes.
- Under a changing climate, when disproportionate costs are used as a reason for an exemption, provide a robust evidence base that considers costs of measures and benefits over a range of timescales and climate projections.
- Assess the consequences of using exemptions on making water resources more resilient to climate change.

7.6 Economic analysis

Guiding principle

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

Changing climatic conditions do not change the requirements and steps in the implementation of the economic analysis of the WFD. There is still the need to follow the sequential steps for the economic analysis of the WFD, but with the integration of potential additional pressures, impacts and constraints due to climate change.

Annex III of the WFD sets out that economic analysis should be carried out for recovery of costs of water services (and that this should take account of long term forecasts in supply and demand for water in the RBD) and for judging cost effective combinations of measures. Figure 2 below gives a reminder of how economic analysis should be integrated into the RBM decision making; this approach remains the same under changing climate conditions.

Member States have taken markedly different approaches to economic analysis and so the way in which consideration of climate change might be incorporated will vary. However it is recommended that, in whatever methodology is used, the required long term forecasts in supply and demand for water incorporate scenarios for climate change. In addition, in assessing combinations of measures, options should be sought that can be shown to perform (and be cost effective) under a wide bandwidth of scenarios for future climate change (see also chapter 7.7 of this Guidance).

Also the justification of lower objectives because of disproportionate cost should consider these long term climate changes. The cost-benefit ratio might change over time and not taking action at an early stage might increase the overall costs for adaptation, e.g. reducing water abstraction for irrigation might be seen as disproportionate because of the loss in income of farmers. However, if water becomes even more scarce, the costs for farmers quitting their business might be higher in the long run. Equally, requiring farmers to install winter storage reservoirs for irrigation could increase costs if they will not be allowed sufficient water to fill them within the payback period of the asset.

Suggested actions

- Carry out an assessment of the impact of climate change on the long term forecast on supply and demand in your river basin district. Integrate these projections into the economic assessment of water use.
- Carry out sensitivity testing based on climate change projections within cost benefit assessment of measures. Give preference to those measures that are robust or flexible to a range of possible climatic futures.

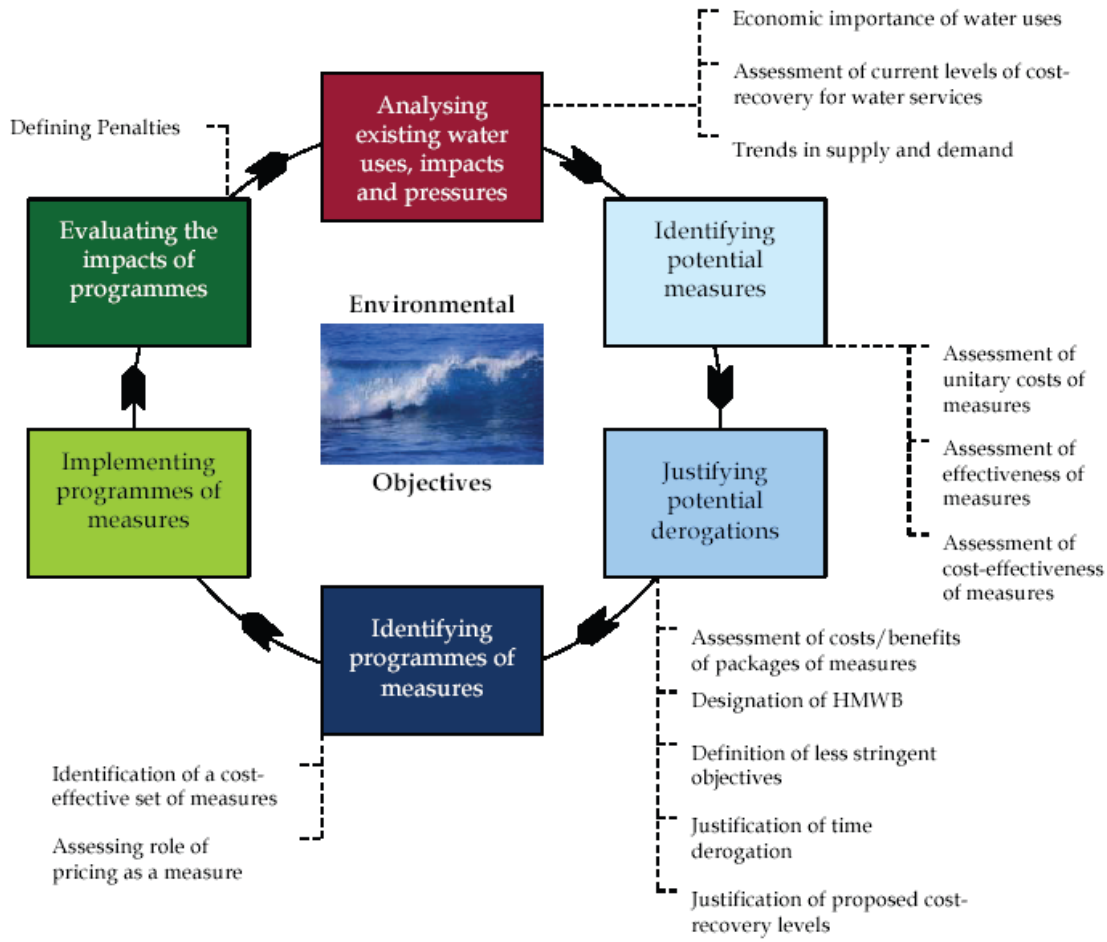


Figure 2 Integration of economic analysis in the RBM decision making process for WFD[29]

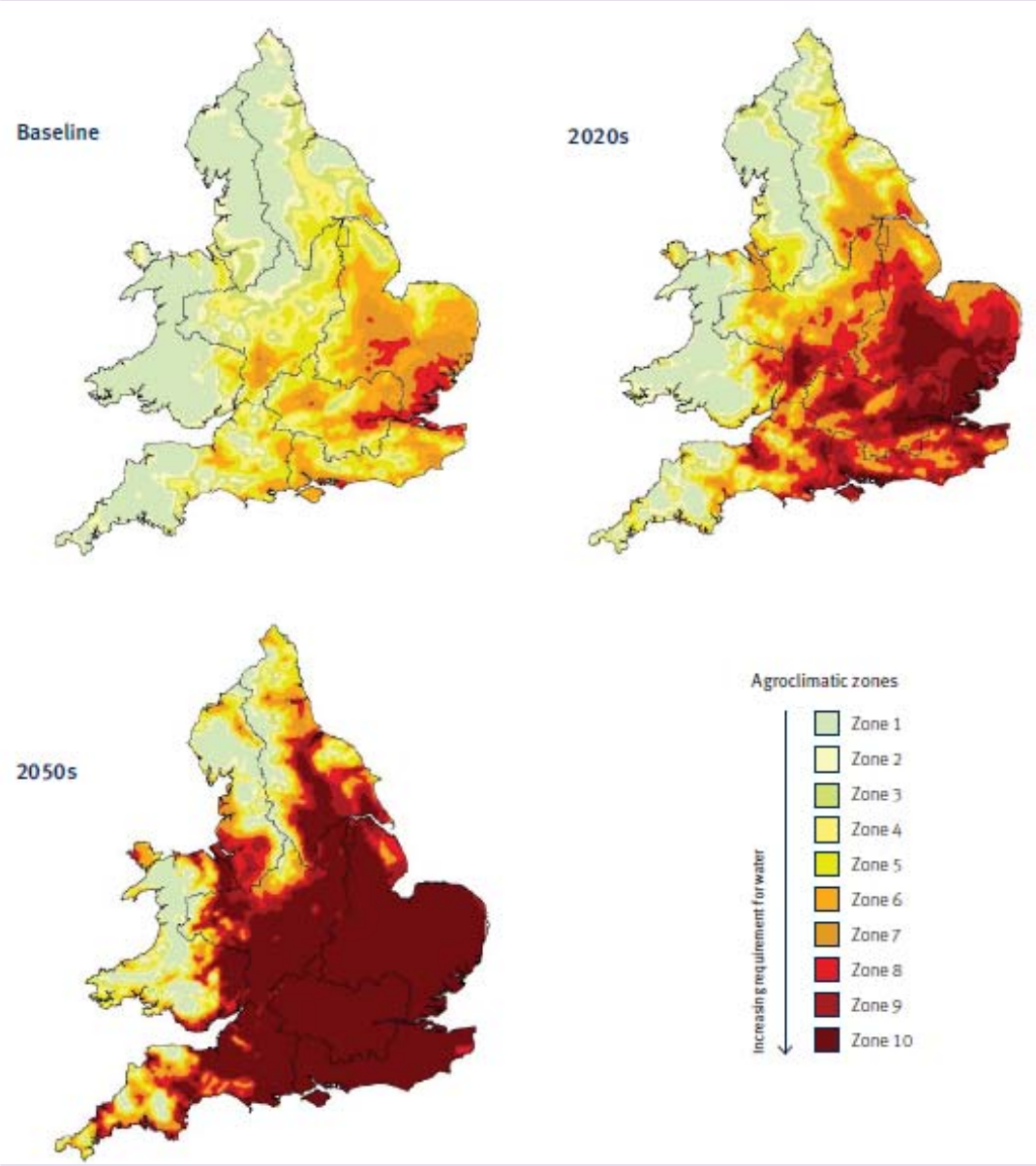
Example 7n – assessing future agricultural water use in England and Wales

The most significant use of water by the agricultural community is for irrigation. Demand for irrigation is concentrated mainly in East Anglia and parts of the Midlands. Despite currently only accounting for around one percent of total abstraction, irrigation is concentrated into a few months when water resources are most scarce, and little of the water is returned to the environment. On a hot dry day in summer, there can be more water abstracted for irrigation in some catchments than for public water supply.

For agriculture, the potential impact of climate change on increased demand is expected to be high. The figure below shows that potential irrigation requirements could increase dramatically, and could move northwards and westwards in the UK as a result of climate change. By the 2020s, central England and eastern margins of Wales could experience conditions similar to those currently typical of the south and east of England. By the 2050s we expect to see a substantial increase in the demand for agricultural irrigation under all of the scenarios we considered. These projections can be fed into economic analysis when considering the economic importance of water use and hence the cost effectiveness of future measures (e.g. winter storage reservoirs or efficient irrigation) to avoid

[29] CIS WATECO Guidance Document 1 on the Economics Supporting the WFD.

environmental deterioration.



Example 7o – Comparison of options for managing abstraction pressures

Under current conditions abstraction pressures within a particular river basin district mean that good ecological status is not being achieved and measures are needed in response. Both development of new water supplies and introduction of new demand management measures are being considered. Incorporating climate change scenarios in the water resources zone model gives that by 2050 the river basin district is likely to become between 10 and 30% drier. Combinations of measures are developed on the basis of current pressures. There is a marginal difference in cost between the two least cost options - a) a new reservoir and introduction of metering, and b) the slightly cheaper possibility of a new reservoir and leakage reduction in the supply network. These are then sensitivity tested against the projected future water resources availability. Whilst both have flexibility to be adjusted through time to enable them to perform over the full range of projected climatic futures, the costs for adjusting option b) rise much more sharply than for option a). On this basis option a) is chosen.

In cases with metering already introduced and/or relatively high leakage rates, the choice would be

different. Leakage reduction can be an important instrument worthwhile for realizing sustainable water use.

7.7 Measures for adaptation related to the WFD

7.7.1 Introduction

What to find in the following sections on measures?

After laying down principles for taking climate change into account in other steps of river basin management (RBM) under the WFD (see previous sections in this chapter), let us focus on related adaptation measures, including the role climate change may have on the WFD programmes of measures.

In a first step (section 7.7.2), we will discuss the need to assess the WFD programmes of measures or individual measures with regard to the impact changing climate conditions may have on their effectiveness for achieving the WFD objectives. The aim should be to enhance the robustness of the programmes of measures against changing climate conditions.

Beyond ensuring the robustness of individual measures and programmes of measures, there might be a need to take specific actions to achieve good water status.

Although, as already explained, it is unlikely that climate change has such impacts on water bodies that it will jeopardise the achievement of the WFD objectives on the short term and that related measures have to be taken, some guidance at general level will be provided in case this may happen.

In addition, when the Programme of Measures (for the 2nd and 3rd cycle) contains major investments for the long term (e.g. building new or upgrading urban waste water plants), climate change needs to be incorporated, even when it is unlikely that significant climate change impacts will occur in the next river basin management cycles. But climate change projections for the longer term may show significant impacts, thus it may be beneficial to already adjust the measures that are taken now (or in 2020) to the long-term predicted changes.

In section 7.7.3, we will discuss the influence of adaptation measures which serve other purposes related to water (e.g. guarantee water supply, flood protection, sustain tourism, etc.) which may impact on achieving WFD objectives. These measures are more and more being planned. Also water management measures for mitigating climate change may have an influence on achieving WFD objectives. These potential impacts and influences have at least to be considered in the planning process.

The following sections do not aim at collecting all measures that are available for adapting to climate change related to the WFD, but rather focus on the consideration of adaptation measures by those with river basin management responsibilities based on current knowledge and tools, and on measures resulting from the principles set out in the previous sections of this chapter. Instead of being overambitious about the details of adaptation achievements in the long-term, this chapter **concentrates on measures and actions that can be taken already in the 2nd and 3rd RBM cycles of the WFD to start adapting our water resource environment to climate change.**

Please note…

The pressures and impact analysis as required by WFD and mentioned in previous sections of this chapter provides relevant input to the climate change vulnerability of a given area, especially on the short term (i.e. the 6 years WFD planning cycle). However, a longer term

vulnerability assessment is needed to assess the effectiveness of the Programme of Measures (7.7.2).

As stated earlier, the WFD offers important tools for adapting to climate change impacts, but sometimes it is not easy to distinguish regular water management issues and measures from adaptation measures.

Specific measures related to flood protection and drought management and the interlinkages with the WFD are addressed in Chapters 8 and 9.

Check also Annex I of this Guidance for a non-exhaustive list of key sources of information on adaptation measures and actions with regard to water in Europe.

7.7.2 How to do a climate check of the Programme of Measures?

Guiding principles

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 (as explained in section 7.3).
8. Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including greenhouse gas emissions.

Due to the fact that substantial financial resources will be invested within the next river basin management cycles, and that many measures and investments will have a long lifespan and will not necessarily include the possibility of adjustments, Member States/RBD authorities have to screen the potential effects of climate change and to undertake a "climate check" of the Programmes of Measures (PoMs).

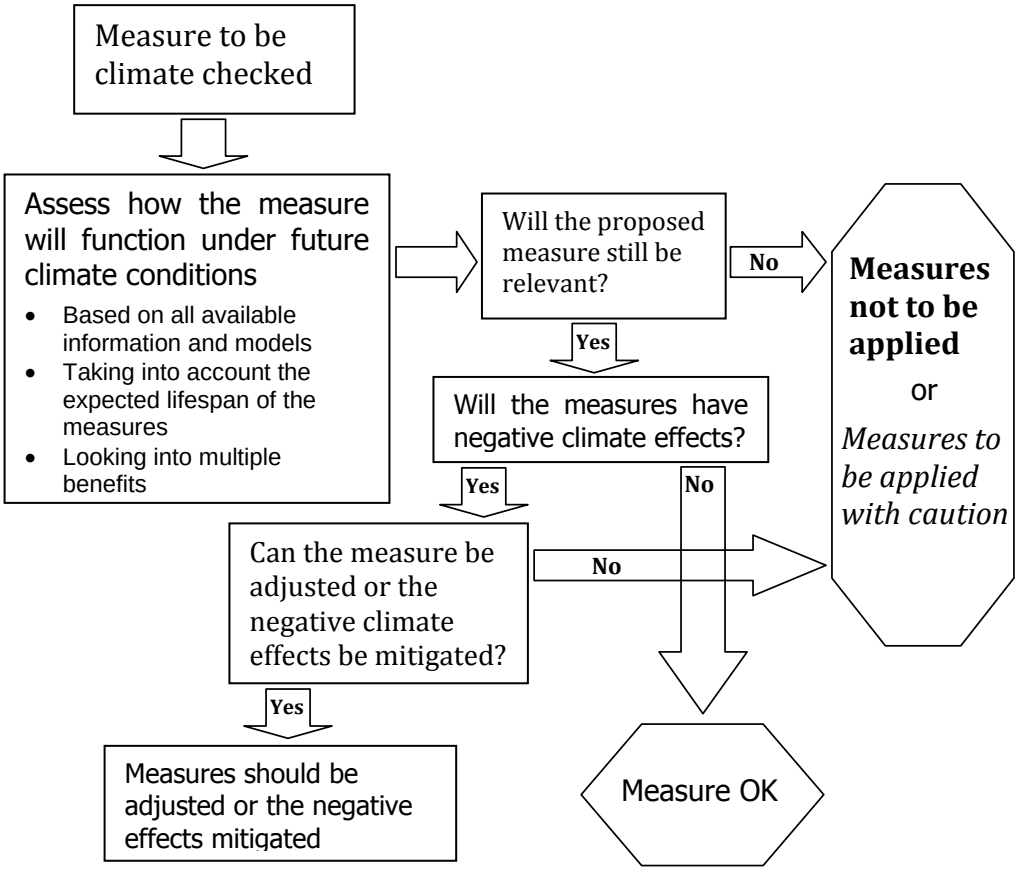
The overall aim of the climate check is to ensure that the PoMs are sufficiently adaptive to future climate conditions. The climate check should provide a form of sensitivity analysis for the selection of measures that are effective, robust and cost-efficient under changing conditions. Additionally, it should ensure that the measures are beneficial to the objectives of the river basin management plans both now and in the future.[30] Check example box 7t for assessing measures for adaptation, identifying advantages and disadvantages and defining whether and under which circumstances a measure could be classified as relevant for water management in RBMPs.

In the subsequent RBM cycles, the Programme of Measures needs to undergo a climate check as a default and firmly based on scientific evidence, notwithstanding the fact that knowledge and new data are constantly evolving (CIS-WFD, 2008-3).

[30] Already in the first RBMPs, there have been some activities in the Member States on climate checking of PoMs. A survey with responses from 21 EU Member States plus Norway during the summer 2008 is available. See report CIS WFD (2008). Progress report on incorporating climate change in the first River Basin Management Plans. November 2008.

Generally, only measures that are robust to climate change impacts and do not increase the burden of climate change should pass the climate check and should be considered in future RBMPs. The flow chart of climate checking measures is illustrated in Figure 3.

Figure 3 Climate checking of measures



Each climate checking of PoMs should involve an evaluation on the level of individual measures, or on categories of measures, so as to determine if the respective measures are robust to future changes.

First, the sensitivity of the measure should be evaluated against the anticipated future climate conditions as each measure or group of measures has its own sensitivity. In cases where the measure is sensitive to the anticipated future climate conditions, it has to be re-evaluated and potentially adjusted so that it is more robust to future climate conditions.

Because of often limited knowledge and a certain level of uncertainty concerning the impacts of climate change on the water bodies, **the best option is to favour measures that can cope with a range of future climate conditions and are sufficiently adaptive to these**. This will minimise risks associated with implementing measures whose effectiveness at achieving WFD objectives could be compromised by climate change even in the face of high uncertainties.

If the sensitivity/vulnerability of a measure with respect to its intended effectiveness is **high**, it has to be checked, whether this vulnerability affects the overall advantageousness of the measure. To ease the process, more detailed analysis should concentrate on measures that are likely to be affected by climate change.

It is crucial to document the process and methodology of the climate check of measures in the RBMPs. This allows repeating the check at a later stage when more or better projections

become available. The documentation of the climate check should be followed by appropriate monitoring to evaluate the results of the check.

Suggested actions

- Evaluate sensitivity of measure against future climate conditions
- Use an appropriate range of future climate projections when checking measures, including uncertainties. The limitation of the range of projections is given by the feasibility of the sensitivity assessment.
- Document the process and methodology of the climate check of measures in the RBMPs.

7.7.3 What to do if other responses to climate change are impacting on the WFD objective of good status?

Guiding principles

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.

There is an opportunity for many adaptation measures to support the achievement of WFD objectives. These are for example measures that give room for the river for flood protection which also will improve hydromorphological conditions (see Example box 7r for more examples).

There are however some adaptation measures that will actually be counterproductive for the water environment, and these should be avoided as much as possible. **In case there is no chance to avoid those measures, they need to meet the conditions set in Article 4.7 of the WFD on new modifications** (see CIS WFD policy paper on Article 4.7 exemptions). Application of the Article 4.7 conditions may still lead to the conclusion that better environmental options exist for the planned measures, which have to be undertaken instead of the planned measure.

In case no better environmental options exist, all practicable steps to mitigate the adverse effect of the concerned adaptation measure have to be taken. Article 4.7 (WFD) provides a possibility to be exempt from achieving good status because of a new physical alteration of a water body, when the benefits of, for instance, taking measures to improve public safety are deemed more important than the benefits for the environment.

It may also occur that certain climate mitigation measures have adverse effects on the water environment, and then the same guiding principles apply. This may be the case for e.g. hydropower development, improved inland waterway transport and biomass cultivation.

Example 7p – Modelling measures and climate change impact in Sweden

Various measures for reducing nutrient load have been modelled using the HBV-NP model in the Rönneå catchment (1900 km^2) of Southern Sweden. It was stated that water quality objectives can be reached by different strategies, which will affect different polluters and social sectors. However, no single measure to reduce the nutrient load was enough in itself, but a combination of measures would be necessary. The cost-effective strategy could reach the goals at 20% of the cost compared to the most expensive strategy examined (Arheimer et al., 2005). The cheapest measures were then allocated where they were simulated to be most effective, and included changes in farming practices (with an increased use of spring crops, catch crops, fertilization in spring and buffer strips), construction of wetlands on arable land close to large point sources, and upgraded waste water treatment facilities in rural private households.

The impact of climate change was examined for the phosphorus load and for the implementation of the examined present cost-effective combination of measures. The modeling was based on the ECHAM4/OPYC3 B2 scenario, downscaled with the RCA3 model and a complementary scaling procedure. Hydrology and phosphorus concentrations were simulated for the time period 1961–2100, using the ICECREAM model for arable leaching and HBV-NP model for integrated catchment analysis including all sources, erosion and major turnover processes at the catchment scale. The results show 10% increased phosphorus load with present land use and emissions in a future climate (Fig. 1). When incorporating the cost-effective measures in the model, the total transport is reduced by 28% compared to the present situation, but as climate change impact evolves, the effect of the measures is significantly reduced (Rosberg and Arheimer, 2007). In 2090, only 12% of the reducing effect remains, and it can be concluded that the chosen measures are rather climate dependent. Thus, climate change must be considered when establishing future objectives and programmes of measures according to the Water Framework Directive. Climate-proof measures should be high-lighted.

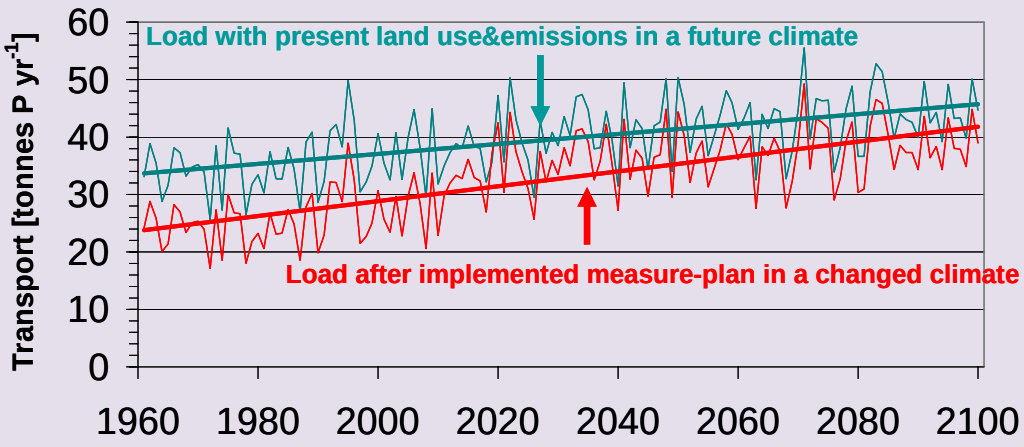


Figure 1. *Simulated phosphorus load in the Rönneå River in a changed climate based on present land use and emissions, and a cost-effective programme of measures, respectively. Trend lines are given (from Rosberg and Arheimer, 2007).*

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Swedish Meteorological and Hydrological Institute (SMHI), Norrköping

-Arheimer, B., Löwgren, M., Pers, B.C. and Rosberg, J. 2005. Integrated catchment modeling for nutrient reduction: scenarios showing impacts, potential and cost of measures. Ambio 34(7):513-520.
-Rosberg, J. and Arheimer, B. 2007. Modeling climate change impact on phosphorus load in Swedish rivers. In: Water Quality and Sediment Behaviour of the Future: Predictions for the 21st Century, IAHS Publ. 314:90-97.

Example 7r - Sectoral adaptation measures that may positively interact with the WFD environmental objectives

Sector	Adaptation measures/actions
Flooding	*Strengthening existing protection, construction of new protection structures e.g. c*onstruction of new dykes and dams or tidal barriers; enhancing capacity of sluices and weirs and adapting the design factor for flood protection measures
	*Making room for water/increasing natural retention and storage capacity e.g. c*onstruction of artificial side channels, reconnection of old river arms: and increasing water transport and retention capacity of floodplains.
	Risk-based planning and building resilience
	Forecasting and early warning systems
	Protection against urban flooding including upgrading of storm drain capacity; increasing soil infiltration and water retention use of wetlands
Water scarcity and droughts	*Water demand management* e.g. putting price tag on water; improving water conservation and water efficiency, raising public awareness for water-saving behaviour
	Supply management and increase reuse and alternative sources e.g. development of water infrastructure, rainwater and greywater harvesting, appropriate use of irrigation reservoirs, matching different water qualities to different uses
	Water allocation and planning including making new housing development water neutral and drought management plans (DMPs) and ensuring environmental flow
Other sectoral adaptation measures	*Spatial planning, land use changes and urban development e.g.* Water assessment for new spatial development and transboundary flood management through spatial planning
	Agriculture e.g. reducing water demand and improving *w*ater use efficiency: changing farm practices on irrigation, soil moisture conservation practices; reducing fertiliser and pesticide use.
	Water services in water resource planning the impact of climate change on water availability and water demand have to be taking into account and demand management measures on water conservation and saving may need to be strengthened.
	Energy e.g. different location for power plants (cooling water) and evaluation of the impact of climate change on hydropower production and dam safety
	Navigation e.g. providing sufficient water depth in times of low water flow. But also navigation use might in turn benefit certain aquatic species; any requirement for increased water storage to support navigation infrastructure might similarly be combined with habitat creation initiatives; integrated sediment management planning could aim to offset any potential new dredging requirements by identifying measures, such as buffer strips, which aim to prevent additional sediment (and associated nutrients, pesticides, etc.) entering the watercourse.

Example 7s – Mitigation and adaptation to climate change in the Seine Nord Europe Canal Project

The Seine Nord Europe Canal is to be the link of the Central European Seine Scheldt Waterway. The high-capacity river network in northern France is to be connected to 20,000 km of European high capacity waterways, in particular in Belgium, the Netherlands and Germany.

The Seine Nord Europe project has been specifically designed to cope with the possible challenges created by changes in meteorogical and climate conditions. Possible trends in water and temperatures parameters have been integrated in the design, building and exploitation phases of the project, including:

- adaptation to water availability (e.g. waterproofness; optimisation of water management; water storage)
- adaptation to extreme temperatures changes impact on infrastructures quality (e.g. dams)
- adopting mitigation measures on the canal building project (e.g. life cycle carbon footprint; reduced road emissions; energy neutrality or energy positive through renewable generation).

Example 7t – Criteria to help selecting adaptation measures

Criterion	Sub-criteria	Guiding questions to be asked
Effectiveness of adaptation	Adaptation function	Does the measure provide adaptation in terms of reducing impacts, reducing exposure, enhancing resilience or enhancing opportunities?
	Robustness to uncertainty	Is the measure effective under different climate scenarios and different socio-economic scenarios?
	Flexibility	Can adjustments be made later if conditions change again or if changes are different from those expected today?
Side-effects	No regret	Does the measure contribute to more sustainable water management and bring benefits in terms of also alleviating already existing problems?
	Win-win (or win-lose)?	Does the measure entail side-benefits for other social, environmental or economic objectives? E.g. does it • contribute to closing the gap between water availability and demand? • affect the delivery of other WFD objectives (e.g. river flow)? • create synergies with mitigation (e.g. does it lead to decreased GHG emissions)?
	Spill-over effects	Does the measure affect other sectors or agents in terms of their adaptive capacity? Does the measure cause or exacerbate other environmental pressures?
Efficiency/ costs and benefits	Low-regret	Are the benefits the measure will bring high relative to the costs? (If possible, consider also distributional effects (e.g. balance between public and private costs), as well as non-market values and adverse impacts on other policy goals)
Framework conditions for decision-making	Equity and legitimacy	Who wins and who loses from adaptation? Who decides about adaptation? Are decision-making procedures accepted by those affected and do they involve stakeholders? Are there any distributional impacts of the climate change impacts or of the adaptation measures?

		Feasibility of implementation	What barriers are there to implementation? • Technical • Social (number of stakeholders, diversity of values and interests, level of resistance) • Institutional (conflicts between regulations, degree of cooperation, necessary changes to current administrative arrangements)
		Alternatives	Are there alternatives to the envisaged adaptation measure that would e.g. be less costly or would have fewer negative side-effects?
		Priority and urgency	How vulnerable are the water uses, the ecosystem and the region? Are there other trends to consider, e.g. demographic trends? When are the climate change impacts expected to occur? At what timescales does action need to be taken?

8 FLOOD RISK MANAGEMENT AND ADAPTATION

8.1 Introduction

Why is it important to take climate change into account in flood risk management?

Although no significant general climate-related trend in extreme high river flows that induce floods has yet been detected[31], **there seems to have been an upward trend in flood occurrence in at least some European rivers in the recent past**. For instance, in Europe twice as many river flow maxima occurred between 1981 and 2000 than between 1961 and 1980[32]. In the Nordic countries, snowmelt floods have occurred earlier because of warmer winters[33]. In Portugal, changed precipitation patterns have resulted in larger and more frequent floods during autumn, but also to a decline in the number of floods in winter and spring[34].

In general, the upward trend in flood occurrence is not ubiquitous and certainly cannot be unambiguously related to climatic changes[35], as long-term trends in hydrological variables are often masked by the significant inter-annual to decadal variability. Also, confounding factors such as land-use change and water management practices have considerably changed the natural flows of water, making it difficult to detect climate change-induced trends in the occurrence and intensity of floods. Even high flows in the rivers combined with high or higher levels in the sea have led to higher frequencies of flooding in coastal areas. Moreover, in the case of extreme floods, given the small probability of occurrence, it is necessary to use long time series to detect trends.

Nonetheless, **future changes in the intensity and frequency of extreme precipitation events combined with different land use policies are likely to cause an increase in flood hazard across much of Europe**, although in the more northern and mountainous areas the risk of snowmelt floods and ice jams in spring may actually be reduced owing to rising temperatures[36] (see also chapter **0** for relevant conclusions of EEA/JRC/WHO (2008)). Due to intensified precipitation patterns, the likelihood of larger intensity of flash floods and pluvial floods across Europe is becoming bigger. The nature of flood hazards may also change; for instance, it is foreseen that in Finland flood risk related to lakes and reservoirs may increase in the South, whilst fluvial floods may decrease. In many places the expected impacts on large river systems are still very uncertain. A number of studies have attempted a quantitative assessment of changes in flood hazard due to climate change in a number of European river catchments[37].

Despite these uncertainties, for countries such as Sweden, Finland and UK, where more in-depth vulnerability studies on climate change impacts on flood risk have been carried out, the

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[31] Becker and Grunewald, 2003; Glaser and Stangl, 2003; Mudelsee et al., 2003; Kundzewicz et al., 2005; Pinter et al., 2006; Hisdal et al., 2007; Macklin and Rumsby, 2007

[32] Kundzewicz, 2005

[33] Hisdal et al., 2007

[34] Ramos and Reis, 2002

[35] Kundzewicz et al., 2005

[36] Dankers and Feyen, 2008; Dankers and Feyen, 2009

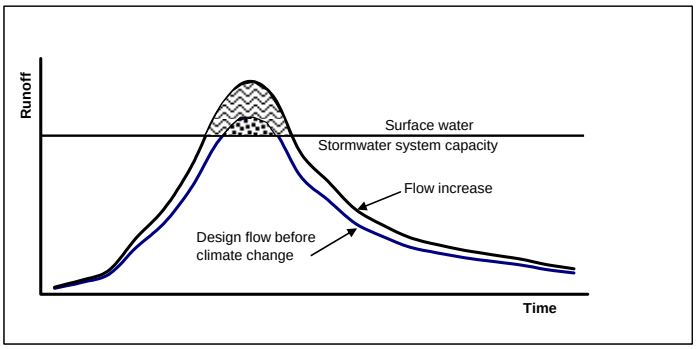
[37] e.g., Booij, 2005; Dankers et al., 2007; Graham et al., 2007; Kay et al., 2006; Lehner et al., 2006; Lenderink et al., 2007; Shabalova et al., 2003; Dankers and Feyen, 2008

conclusion is often that although the information is uncertain it is robust enough to warrant that adaptation action can already be started.

Since there are major variations from year to year, studies are required over long time periods in order to be able to draw relatively reliable comparisons. The scenarios may also differ both in impact and certainty depending on whether the timeframe is mid-term (e.g. 2030) or long term (e.g. 2100). It is necessary to use reference periods while interpreting and validating the scenarios. The effects of climate change on the probability of floods can furthermore only be calculated in detail based on a river basin approach.

Due to climate change, the probability of different types of floods is likely to change, and it may lead to increased flood risk if additional measures are not taken. Due to marked differences between different types of floods - e.g. coastal floods, flash floods and urban floods - measures to be considered throughout the flood risk management cycle should correspond to the challenges of these distinct types (see Annex III for details on these challenges).

An illustration of the uncertainties of changed flood risk with climate change is that although precipitation may change by a certain percentage, the associated increase in flood damage may be even more difficult to assess.



A small change may end up…

Heavy rain in the city of Fredrikstad: Number of houses flooded after 15 % increase in precipitation nearly doubles!

Historical 20 yr-rain June 25, 1988
Historical 50 yr-rain July 10, 1979

Rain	Number of houses	Change (number)	Change (%)
20-yr	22		
20-yr + 15 %	41	19	86
50-yr	62		
50-yr + 15 %	115	53	85

Modelled by Halvor Hardang
Master thesis 2007, UMB

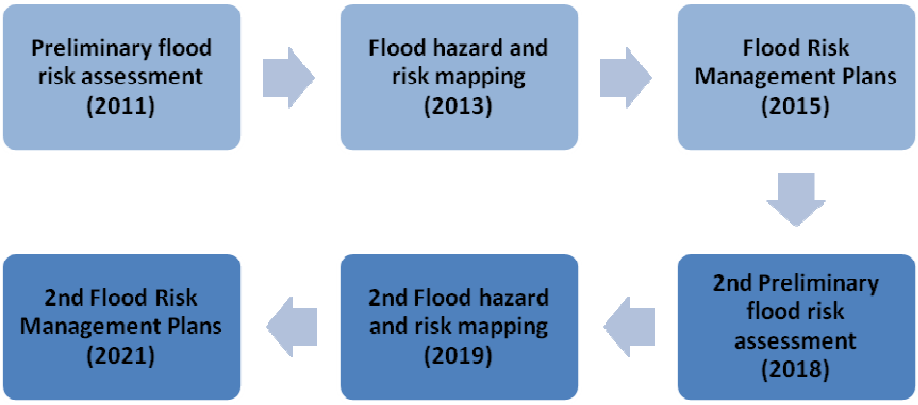
Figure 4: **Relationship between increase in runoff and potential damage.** When engineers plan the stormwater/sewage system, part of the stormwater is designed to run on the ground surface under heavy precipitation, because it is too expensive to include rare precipitation episodes in the drainage system. As a result, a small increase in rainfall intensity may increase surface runoff several times. Hence, inundation of houses is likely as the climate changes (Figure: O. Lindholm and B.C. Braskerud). For instance, in a part of the Norwegian city Fredrikstad (close to the Swedish border) a 50-year rain usually floods 62 houses. With an increase in precipitation of only 15%, 115 houses will be flooded due to overload of the combined stormwater/sewer system (Modelled by Halvor Hardang, Master thesis 2007, Norwegian Univ. of Life Sciences).

What can you find in this chapter?

As explained in chapter 4, the key steps of the flood risk management cycle in the Floods Directive are preliminary flood risk assessment, flood hazard and risk maps, and flood risk management plans.[38]

Figure 5 Steps of flood risk management cycle in Floods Directive

[38] Note that the PFRA does not necessarily have to be carried out where an area is already subject to mapping and planning (Art 13.1.b).



Climate change also needs to be taken into account throughout the full flood risk management cycle. Different examples are given below. The Floods Directive furthermore needs to integrate risk management throughout the implementation cycle, which among other things requires a multi-hazard approach, and for instance that the risk assessment places safety issues at its core.

This chapter of the Guidance follows these main steps of the Floods Directive to explain how climate change should be incorporated. The Floods Directive states that the preliminary flood risk assessment (Article 4, FD) shall be based on, among other things, the "impact of climate change on the occurrence of floods" from the first cycle, and article 14.4(FD) states that the "likely impact on climate change on the occurrence of floods shall be taken into account in the reviews [of the preliminary flood risk assessment and the flood risk management plans]".

The need for EU and MS action to ensure that climate change is taken into account in the implementation of the Floods Directive was emphasised in the EC White Paper on Adaptation.

The purpose of this informal document is to provide guidance to river basin managers and flood risk managers on how best to take climate change into account in river basin management, already from the 1st implementation cycle of the Floods Directive.

In addition to the guiding principles in the sections below, one overall guiding principle covering all steps of the implementation of the Directive, as well as the full flood risk management cycle, can be highlighted:

Overall guiding principle

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 the case. Follow the guiding principles set out for the WFD.

A general question to be considered in the implementation of the Floods Directive is if the potential changes to flood risks induced by climate change require a changed flood risk management approach. Examples are: changes of duration, intensity and frequency of floods, intensified coastal flood risks (related to both sea level rise and increased storm surges), floods in ephemeral rivers (in particular in drying regions), changed patterns in snowmelt, ice-jam floods and more regulated rivers due to hydropower production. Flood risk management should take into account the impact of climate change on the hydrological behaviour of the catchment, both in natural (reference) and altered (modified) conditions - for instance rivers regulated for hydropower production or with flood defences - since it may

change the floods regime; this requires the integration with the river planning process under the WFD. Risk reduction responses may also include different approaches to land use planning, the role of climate change in civil protection policies, and learning to live with and adapt to floods preventing them is not possible.

8.2 Preliminary Flood Risk Assessment

Guiding principles

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.

The FD established that the potential impacts of climate change must be considered within the preliminary flood risk assessment from the first planning cycle, based on the available information.

There are likely to be challenges and limitations on the degree of consideration of climate change in undertaking the preliminary flood risk assessment (PFRA), particularly in the first cycle, given the qualitative rather than quantitative information that may be available or readily derivable. This knowledge is foreseen to be improved in the second cycle (after the first flood maps and flood risk management plans).

Working with models, scenarios and projections

Chapter 5 of this Guidance discussed the use of different climate models, scenarios and projections. A set of guiding principles on decision-making and management of the water environment under uncertainty of models and projections was put forward. Those guiding principles are also valid for flood risk management.

Improving trends detection

One of the most difficult things to predict is changes in trends. Based on available information, scenarios are built with a significant amount of uncertainty around them. For climate change, the horizon of the scenarios is often 50 to 100 years, while climatologists even look at 2300. On the other hand, no or little information about land use scenarios more than 30 years ahead is available and geographically the scale is rather rough. Maps with arrows and shaded zones indicating where changes are expected are difficult to put into GIS-systems for scenario calculations. The same is valid for demographic changes: long term perspectives indicate birth, death and migration rates but local evolutions find only very limited expression in these tables. The issue of field significance and regional consistency for trend detection in hydrological extremes is addressed in one of the examples below.

In general, it is proposed to improve trend detection methods, using the information gathered over the Floods Directive implementation cycles detecting trends of changing flood patterns.

To enable improved trend detection it is also important to continue monitoring of occurring floods in the coming years. The PFRA requires that past floods be taken into account. Existing information on past floods (as of today) is one important component, but it will also

be important to collect information on new floods that will occur, and which will be considered as "new old" floods in the next implementation cycle. In this context, it is proposed to develop a structure for gathering information on past floods, to enable a large, consistent and comparable set of data to be used for the detection of climate change signals concerning all types of floods and adapted to the rules and guidelines of INSPIRE (2007/2/EC).

It is also important to work further on homogenizing and removing bias from timeseries of past floods, in order to detect climate change signals. One example is an increase of high probability floods (low return rates) in certain Austrian rivers since the 1960s, which is however attributed to structural measures related to the straightening of rivers rather than climate change.[39] It is also important to use time series that are as long as possible as well as relevant for the type of flood event investigated.

Using information availability under WFD

In particular, the following information derived under the WFD is of particular relevance for the purpose of assessing climate change related aspects of the Floods Directive:

- Flow levels to assess changes in normal flow regimes.
- Physical modification of water bodies, sediment transport, etc.
- Characteristics & impacts of human activities, e.g. information on polluted soil, identification of point and diffuse sources, etc.

Particularly all those signs and signals due to climate change, such as spatio-temporal irregularity of flow regime and available water resources, can be used to improve flood knowledge, and must be taken into account in the preliminary flood risk assessment.

Furthermore, coordinated implementation of the two directives will enable information exchange and use to be optimized and for relevant information gaps to be identified.

Working with "readily available information" on climate change impacts on flood risk

Article 4§2 of the Floods Directive states that the PFRA shall be carried out "based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods". The identification of such information at different scales (RBD/UoM, national, EU) is therefore important.

In addition, identifying the kind of information which it would be beneficial to develop at different scales, can help guiding research projects in the timescales relevant:

- more information on "paleo" floods/past floods to support long-term trend assessments.
- further information to be made available via GMES, notably for reviews.
- elevation maps needed for both maps/PFRA.

Using best available information - links to insurance industry

[39] Blöschl G., Merz R. (2008). Bestimmung von Bemessungshochwässern gegebener Jährlichkeit – Aspekte einer zeitgemäßen Strategie (Estimating Design Floods of a Given Return Period – Facets of a Contemporary Strategy). Wasserwirtschaft 11 (2008): 2-11.

In the view of climate change increasing flood risk-related pressures, it is in everyone's benefit to share data, and from the insurance industry's perspective there is no competitive advantage in not sharing data with all stakeholders involved. Transparency of information therefore needs to be improved, not the least from the side of the insurance sector. The role of insurance in the recovery phase of the flood risk management cycle is important in several countries. Despite several good examples of information exchange, changes to the insurance culture may be needed and the information needs to be made available to local authorities as well as flood risk managers. The detailed and high quality information of insurance and reinsurance industries gathered during the recovery phase of a flood is of help for water managers and local authorities to improve their plans for the prevention, preparation and protection phase, which is important for all stakeholders.

Information exchange with the insurance industry should therefore be reinforced, for the purpose of using the expertise available for risk assessment throughout the flood risk management cycle, including collection of data for hazard mapping, and improving prognosis and decision making under uncertain conditions, including economic development.

Example 8a: HORA – Flood Risk Zoning Austria

HORA is an Austria-wide risk zoning system (www.hochwasserrisiko.at) for natural disasters, presently prioritising floods and earthquakes. This project has been jointly implemented by the Federal Ministry for Agriculture, Forestry, Environment and Water Management and the Association of Austrian Insurance Companies (Verband der Versicherungsunternehmen Österreich VVO) on more than 25,000 river kilometres. A central finding of the 2002 flood, caught up from the study "FloodRisk", was that besides raising people's risk awareness, indicating the limits of active measures of risk protection and the necessity of the adapted use of endangered areas, a "risk partnership" between state, insurance companies and individuals would play an even greater role in the future. HORA is playing an important part in this cooperation and is a unique project in Europe in the cooperation between the state and the private sector. The beneficiaries of this cooperation are to be the citizens of this country when it comes to providing important information, for example on the risk of flooding of one's home or of an industrial enterprise, an infrastructure facility, etc. In addition to obtaining easy and quick information about any risk of flood via a digital internet hazard map, which serves as a first risk assessment as well, this tool can also be used to optimise and set priorities in the required flood control at the municipal, provincial and federal levels.

For the Federal Ministry for Agriculture, Forestry, Environment and Water Management, the project is not only a milestone in the field of risk communication, but also reflects Austria's leading role in the water sector as such. HORA advances parts of the EU Flood Framework Directive which requires more information for the public. What counts for the insurance companies is, apart from higher risk awareness of the people, an improved realising and assessment of potential dangers as a basis of insurability.

Making most of the review of the preliminary flood risk assessment in view of climate change

According to the Floods Directive, there is a need to review the PFRA (Art. 4 and 5) every 6 years. All relevant data should be made use of, with a view of identifying potential changes or trends induced by climate change.

To ensure climate change is properly considered in the reviews of the preliminary flood risk assessment, including the subsequent identification of areas of potential significant flood risk, it is recommended to:

- always use latest available (yet robust) information
- identify "climate change hot spots" which should be subject to more detailed checks and which can serve as trend detection areas and indicators of the vulnerability of certain regions. The need for reassessments shall be considered in each review

period.

- exchange information between MS on climate change impacts, not just between MS sharing water courses but also at a wider scale, so as to raise awareness on changes noted.

Transparency on how to deal with "worst case" scenarios in assessment of potential significant flood risk

In general, when acting under uncertainty it is recommended that many scenarios are investigated and considered. An assessment of potential significant flood risk requires that some kind of "worst case scenario" be considered as a point of reference regarding the worst situation that can be expected, although the measures taken in the planning process may be based on more realistic scenarios. However, for flood risk management planning it may not be practicable to use the worst case climate scenarios as considered by IPCC (such as new ice age, 18 m SLR etc), and the term should be used with care and in such a way that is still useful for planning purposes. Flood risk assessment should typically use a scenario comprising river discharges, sea levels and weather conditions that are considered to have a small though realistic possibility within 100 to 200 years. The extreme discharges, sea levels, etc. may be higher than the design conditions of man-made flood defences.

The latest available climate change information should be taken into consideration. The "worst case" scenario should be clearly described. The periodic review cycles required by the Floods Directive will provide an opportunity to take into account new scientific results regarding climate change.

The term scenario in this context is used for climate change issues and must not be confused with scenarios according to Article 6(3) FD, which cannot be considered under PFRA.

Taking climate change into account when assessing the effectiveness of existing man-made flood defense structures

The Preliminary Flood Risk Assessment requires both an assessment of the effectiveness of existing man-made flood defence structures and taking into account climate change related impacts on floods, depending on the need of the Member States.

The "worst case" scenario mentioned in the previous paragraph should be one basis for assessing man-made flood defence structures, depending on how this term is defined and assessed. It should be noted that also without climate change there is a potential risk in areas behind man-made structures.

Suggested actions

Understand and anticipate as far as possible climate change impact on floods

- Monitor changes to flood patterns by gathering comprehensive information on past floods - consider development of a "past floods database at European level"
- Develop a structure for gathering information on past and new floods
- Improve trends detection, using the information gathered over the implementation cycles detecting trends of changing flood patterns

Use best available information

- Anticipate and improve readily available information

- Use monitoring under WFD on flows, physical modifications, pressures and impacts, etc.
- Consider what is "available and readily derivable information" today and what is foreseen to be "available and readily derivable information" in 2011, 2018, etc. (taking into account for instance the forthcoming 5th IPCC AR).
- Exchange information with the insurance industry, as well as land use and spatial planners
- Make the best use of review cycles of PFRA
- Continue further best practice exchange on how to incorporate climate change information in the PFRA at European level

Homogenize time series, and remove bias as far as possible

- Remove bias from timeseries and use timeseries that are as long as possible

Understand and anticipate as far as possible increased vulnerability and flood risk due to climate change

- Take climate change into account when assessing the effectiveness of existing man-made flood defence structures
- Be transparent in the use of "worst case" scenarios – take latest available climate change information into consideration

Example 8b: Trend detection in France

Regional methods for assessing field significance and regional consistency for trend detection in hydrological extremes have been developed and applied to France (Renard et al, 2008). The impact of climate change on hydrological regimes is still an open question: one possible cause of this could be the lack of statistical methods to detect trends in data affected by a very high variability. The results of the study emphasize some of the challenges related to the detection of changes in a non-stationary climate. For example, preliminary analyses showed that many stations from the initial data set were affected by significant changes, but most of these changes could be explained by non-climatic factors, principally measurement problems. Such biases are unlikely to be specific to France and might be encountered in any river flow series.

Example 8c – Detecting and attributing flow changes in southern Germany

The KLIWA project (www.kliwa.de) was set up to look at adaptation strategies for flood protection in southern Germany. As first step, long-term meteorological and hydrological measurement data from Bavarian and Baden-Württemberg weather stations were analysed and trends were determined. The climate conditions in Southern Germany, which have an impact on the entire water balance, have changed noticeably in the past century, especially during the last three decades. In specific regions the trends that have been observed through monitoring exceed the natural margin of deviation, derived from long measurement time series, for some of the variables examined (air temperature, precipitation (regional precipitation, heavy-precipitation 24h and more)). The results agree with the explanation that the global and regional climate is human-induced, but do not yet provide certainty of attribution of changes in extreme floods of river flows to anthropogenic climate change.

Example 8d: Available and readily derivable information in Finland

The Finnish Environment Institute (SYKE) has abundant hydrological data files, e.g. several daily discharge series which have started in the 19th century. These data series have been used in statistical analyses to find out trends in a large set of hydrological variables, including those related to floods. In

general, the flood regime in Finland has not yet changed significantly, although the spring peaks have moved to an earlier date on many locations.

SYKE has also developed The Watershed Simulation and Forecasting System (WSFS), which is operationally used for forecasting various hydrological variables for all river basins in Finland. The inputs of the model are precipitation and temperature, the simulated components include snow accumulation and melt, soil moisture, evaporation, groundwater, runoff and water levels of the main rivers and lakes.

Extensive data files and advanced modeling tools give good possibilities to study also the impacts of climate change to floods. These kind of studies have already been performed, and the work is continuing.

In the present stage of these studies, climate change impacts on floods in Finland by 2010-39 and 2070-99 have been evaluated on 67 sites to get a general overview of changes in floods on national scale. This assessment was done with WSFS modeling tools using climate scenarios from both global and regional models. The flood magnitudes of 20 and 100 year floods and their changes were estimated with frequency analysis. The results can be used to identify areas where climate change may potentially increase the flood risk. (According to these results the floods in Finland may decrease in many areas but increase especially on large central lakes and their outflow rivers.)

The general trend of the effects of climate change will be taken into account when the flood risk in the watershed is assessed in the first PFRA. Not just the change in the peak flow but also the change in the seasonal distribution of floods has to be taken into account. In some watersheds the increase of winter floods may rise the flood risk significantly. More detailed studies may be used later during the following rounds of the implementation of the directive.

8.3 Flood Hazard and Risk Maps

Guiding principles

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

The Floods Directive requires 6-yearly reviews of the flood mapping. Probabilities may change in that timeframe, partly because of climate change but also because of other drivers (mostly shifting probabilities; see further explanations below); the 6-year planning cycle allows for the incorporation of these changes. An extra effort is needed to deal with uncertainties in the mapping phase. By taking on board the changes of flood extent of the different scenarios, the management response as set out in the plans should change accordingly, thus providing a sign on how the cyclical implementation of the directive is useful for climate change adaptation.

It is highly recommended to include additional information which Member States consider useful (see art 6.5.d) for flood prone zones regarding climate change and its effects, for example water velocity maps, water depth, and possible fast occurring changes of stream routes in plan view, as well as slower changes resulting of meander migration. With reference to Article 6.5.d (FD), Member States may consider it useful to analyze and map the role of sediment load, especially in flash floods and taking into account possible increases in soil erosion in watersheds.

Further development of analytical methods to assess flood hazards in a changing climate and cartographic methods may help to display probabilities and uncertainty in flood-mapping products. Further development of mapping methodologies will also be important for different

types of floods where flood patterns are expected to change with climate change: pluvial floods (urban/rural), coastal floods, extreme river floods, flash floods, ephemeral floods, ground water floods, ice jam and frazil ice floods, etc. (see annex III for further information of different types of floods).

For all scenarios it is important to inform map users about the uncertainties. In electronic format maps, this could for instance be done by means of pop-up text. Further information exchange is needed on how to best do this in a consistent manner across the RBD. For instance in transboundary RBDs, it is also important to inform map users about the uncertainties.

Medium probability (at least 100 years return periods)

Due to the effects of climate change, within a period of 6 years there may be changes in intensity and extent of floods and potential changes; what constitutes a medium scenario flood, for instance a 100-year probability flood, may change within the 6 year cycle. Flood maps should take account of this as much as possible if conditions and scenarios change.

Low-probability or extreme events

Most probably, in some parts of Europe, this kind of events may increase in severity; in consequence, considering climate change impact on this scenario is crucial. As high return periods may become more uncertain, this uncertainty needs to be managed.

Low probability events are mainly extrapolations of measurements outside the range of events that occurred in recent history (read: since beginning of measurements). In most simulations and scenarios the extreme events seem to become more severe regarding their consequences. Combinations of uncertain conditions under future circumstances combined with the uncertainty in the scenarios describing future conditions (climate change, land use, etc.) make it difficult to include them in the risk approach (what probability do they get?). While protection against more or less frequent events is a largely adopted solution, a cost-benefit analysis may prove that this approach is not efficient for worst-case scenarios. Measures to minimize the consequences will be different for these worst-case events.

With the flexibility provided by the Floods Directive, the possibility is given to choose between "extreme event" and low-probability scenario. This implies that, for instance in the description of a worst case scenario, ignoring the 'exact' probability avoids discussions focusing on this kind of detail and allows to address the issue of real importance: how to deal with such an event when it happens?

It is thus proposed that the extreme event scenario could be used for anticipating changes to floods related to climate change, in the case that it is not possible to estimate with any accuracy the expected flow changes corresponding to low probability.

High probability flood events

Depending on local / regional circumstances it may be appropriate to include high probability floods in the maps, on the grounds that climate change is also likely to increase the frequency and intensity of events in this category. In some areas they may not differ much from 100-year flood in extent.

One reason for this is the added communication value of hazards and risks related to for instance 20- or 5-year floods.

It is very important that the information from the high probability event scenarios be taken into consideration in the water resources management and disaster risk reduction adaptation efforts. The more frequent a flood event will occur, the more important it is to take robust flood management measures to ensure the increased resilience of society against frequently upcoming events.

It is recommended to review the need for including mapping of high probability events, where this is not already done - in each review cycle, in the light of the possible impact of climate change.

Suggested action

- Make sure best available information (see above under Preliminary Flood Risk Assessment) is taken into account when flood scenarios are reviewed every 6 years.
- Present uncertainty related to climate change in a transparent manner in flood maps.

8.4 Flood Risk Management Plans

8.4.1 Flood Risk Management Objectives

Guiding principles

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.

The Floods Directive requires Member States to set the flood risk management objectives, "focussing on the reduction of potential adverse consequences of flooding and, if considered appropriate, on non-structural initiatives and/or the reduction of the likelihood of flooding". The Flood Risk Management Plans shall in consequence include measures to achieve these objectives. The objectives of the WFD shall also be taken into account when establishing measures. The likely impact of climate change on floods shall also be taken into account in the review of the plans (FD art.14(4)). Member States will decide which types of objectives are set. In the light of the importance of potential impacts of climate change on floods, and the need to anticipate these as far as possible, it is recommended that climate change is taken into account already in setting the objectives for the first cycle of implementation of the FD, and some recommendations be given in the context of further information exchange in relation to the development of Flood Risk Management Plans.

In addition, it is necessary to pay special attention to the environmental objectives of WFD Article 4.1 to see how to best ensure the positive synergies between the two Directive, as some types of floods as well as some types of flood management measures (such as wet land restoration) can also have beneficial aspects for increasing the climate change resilience of ecosystems such as the ecology of the river and floodplain, soil fertility, groundwater recharge, and biodiversity.

When setting the objectives, the safety aspects of flood risk management need to be emphasised in view of climate change, in particular as regards civil protection measures.

Comprehensive policy frameworks exist for planning and decision making, such as Integrated Flood Management[40]. Those are based on risk management principles that recognize explicitly the residual risks on the floodplains while taking a comprehensive perspective of floods, river health, as well as benefits and risks of floodplain use.

Suggested actions

- Indicate how climate change plays a role in setting flood risk management objectives.

8.4.2 Awareness raising, early warning, preparedness

Guiding principle

11. Include climate change scenarios in ongoing initiatives and in planning processes.

Chapter 6 of this Guidance put forward a set of guiding principles that may help those with responsibilities in river basin management in building adaptive capacity for coping with climate change in the upcoming river basin management plans. These principles are also valid for flood risk management and are here complemented with recommendations specific to the flood risk management process.

Education and awareness raising

With climate change, flood awareness is likely to increase, and this needs to be managed in a constructive way, to make sure the right level of concern leads to the right management decisions. Awareness-raising campaigns can be considered as addressed to the public, to local authorities and politicians, and to other sectors influencing flood risk management. Increasing the awareness of increased flood risks, and how to cope with floods, in the education system is also important.

The awareness about the fact that the public can expect less ordinary events coupled with more extreme flood events needs to be raised. This should include education about: source - path – receptor chain and all aspects of safety chain from prevention till recovery.

Education and other public awareness-raising measures would therefore be crucial for preparedness, prevention and protection, and as such can be important measures in future FRMPs.

Involvement of stakeholders

A holistic approach needs all public and private stakeholders to be involved. It is important to raise awareness, but also to help identify acceptable optimal flood risk management measures. An important example is to involve local planning authorities in the process (see further text on land use).

[40] Refer: http://www.apfm.info/pdf/concept_paper_e.pdf

Full use should therefore be made of the consultation mechanism (Art. 9) to ensure active involvement of interested parties in the river basin and flood risk management process, regarding the climate change related role of significant drivers and risk receptors.

Make sure potential changes to flood risk are built into multi-hazard disaster risk reduction civil protection/emergency measures

Climate change may in many areas lead to an increase in number and intensity of hydrometeorological hazards, including weather-driven events like floods. This will create situations where urgent response civil protection interventions will become more necessary. Improving early warning systems, enhancing preparedness on EU and Member State level of simultaneous events, improved preparedness of population and further climate proofing of civil protection, including coordination and funding, will be important to take into account in the planning for future civil protection. Flood risk management therefore also needs to take climate change increased pressures on civil protection more into account in planning. Cooperation between flood risk management authorities, water management authorities and emergency response authorities may need to be improved in some cases.

Suggested actions

- Include climate change related flood risk changes in ongoing education initiatives to improve flood risk awareness and preparedness.
- Improve institutional awareness of potential climate change related impacts on flood risk, for instance ensure that authorities responsible for climate changes adaptation and flood risk management coordinate with river basin management.
- Ensure all interested parties are involved in the consultation process for the Flood Risk Management Plans.
- Increase the resilience of civil protection and disaster management infrastructure in view of climate change.

Example 8e: "Early warning and preparedness"

It is better to be prepared by preventing floods and other consequences caused by climate change. **Early warning** is one important complementary measure to take, but it does not replace the need for preventing climate change happening in the first place. Early warning is also one of the measures that are efficient under current and all possible future climate change conditions: a no-regret measure. The effect of early warning increases when floods can be predicted earlier. Flash floods and cloudbursts cannot be predicted very accurately, neither their geographical occurence nor their time scale. The rise on larger European rivers can be predicted longer in advance, thus allowing for a larger range of actions. Coastal water levels are in general predictable a few days in advance, but a determining factor for flooding to happen is usually the behaviour of defences (dunes, dikes, quay walls, etc.), as it is the case for dike-protected areas along rivers. Breaching causes an immense volume of water flowing into the hinterland with high flow velocities close to the breach.

Preparedness means that all plans and procedures are ready and usable on any moment, that inspections of the current situation are carried out and reparations are done when necessary. In the emergency and response stages, all effort needed to minimize loss of life and damage and that can be considered realistic should be prepared and carried out. The review is adapting the procedures and improving the preparedness phase because the question, with and without considering climate change, is never: "will there be a next event?" but "when will the next event occur?". A red line through all these phases is communication: communication about preparations made by public

authorities and about what people can (or have to) do during the preparation phase; communication as 'take action' commands in the emergency and response phase; and explanation of lessons learned and new insight (e.g. in the severity of climate change) in the review. Communication is not a matter of specialists only and is, in the preparedness and review phase, more a dialogue with all stakeholders than one-way-communication about model results.

8.4.3 Measures

Summary of guiding principles

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 on their impact on flood risks:
    h. Hydropower and flow regulation
    i. Link with water scarcity

The guiding principles are explained one-by-one in more detail in the following paragraphs. Please check also section 7.7 for guiding principles and elaboration on measures for adaptation related to the WFD.

Guiding principle

12. Perform a climate check of flood risk measures

As for other aspects of water management referred to in this guidance, climate change checking of flood risk management measures is crucial. No-regret or low-regret measures should be favoured when considering options (see also guidance provided in chapter 7.7 on measures in general). It will be crucial to consider questions such as "Are planned measures to be taken by 2015 still the best to be taken, knowing that the situation may change in 2050 (especially when a dyke has a lifetime of 50 years)?"

Although changes may not appear in the planning period (2015-2021 for instance) but for instance in 2050, the effects of the mitigation and prevention measures often have a longer

lifetime, and all measures included in the flood risk management plans should therefore be climate checked.

Further examples are given below.

Guiding principle

13. Favour options that are robust to the uncertainty in climate projections

Assessing potential future flood risk is a core task of flood risk management, and the process carries many inherent uncertainties. As climate change only forms part of the flood risk, which also comes from a range of other drivers that have uncertainty attached to them, an assessment of the various factors causing such uncertainty, including climate change, is necessary to manage uncertainties.

The assessment of flood risks and planning to reduce them in view of climate change impacts must be done in an uncertain context. In this particular context, the precautionary principle has to be applied.

Pollution risk in flood prone zones

An area which is heavily polluted requires that the FRMP includes a management response if the area is in a flood zone. Today the hypothesis may be that the area will not be flooded so often, and the management response may be limited as knowledge exists on how to handle the situation under such a hypothesis.

The flood risk management should take into account, however, that the area might flood much more often due to climate change, therefore possibly increasing the flood hazard, and the choice of management mechanisms may be different. This may for instance affect the choices made between building permanent defences, relocating the installation out of the floodable area, or even remove the polluted soil.

Non-structural measures

In recent years, flood management policy has shifted from defensive action towards management of risk and enhancing societies' ability to live with floods via increased use of non-structural flood protection measures. Spatial planning, including regulation of floodplain development and relocation, can consider more 'room for rivers' and could have effects for both floods and low water. Non-structural measures, which do not involve large structural components, can be rated as more flexible, less committing and more sustainable than hard measures. Yet, the latter may be indispensable in certain circumstances[41]. Technical flood protection measures are often necessary to handle the effects of rare major events. Water managers are thus faced with the challenge to **design a site-specific mix of both types of measures, which may be altered or are robust to changing conditions**.

No regret and win-win measures

Another way of dealing with uncertain impacts of climate change is to prioritise "no regret" or "win-win" measures. In this context the flexibility of measures is an important criteria. Dykes that can if necessary be increased in height during an flood event are one example.

Example 8f: Promoting "no-regrets" options in view of climate change

[41] Kundzewicz, 2002

During the pilot Catchment Flood Risk Assessment and Management (CFRAM) studies in Ireland, analysis was undertaken, including flood mapping, of two possible future scenarios based on projections of the impacts of changes in climate and land use. An objective was set within the option appraisal framework to promote adaptability to the effects of such changes within any measures under consideration for adoption within the Flood Risk Management Plan, and the temporal coherence of the Plan was evaluated to promote a 'no-regrets' approach. While the process implemented during the pilot stage will be refined, it is considered that the approach promoted adaptability to climate change within flood risk management.

A win-win measure may furthermore be a measure that at the same time reduces flood risk and has other positive aspects such as improvement of the quality of the aquatic environment, which is the case of wetlands or sustainable urban drainage. Other examples are flood reducing measures having positive effects on generating green energy, recreation, landscape quality etc.

A tool-box of for instance different good practices on sustainable urban drainage could be usefully developed.

The development of a 'catalogue' of possible "no-regret" measures (measure feasible under actual climate conditions and different climate scenarios) at the European level with examples from different parts of Europe, could facilitate the identification of such options.

Mix of measures

Faced with the situation that adaptation activities are necessary, but scenarios are still uncertain, the best option may be to identify the most optimal mix of measures. The catchment approach section below indicates one such example, but this can also entail a mix of non-structural measures such as education, change of private property owners' responsibilities, economic incentives, better forecasting, improved collaboration, as well as improvement/introduction of structural measures.

Guiding principle

14. Favouring prevention through the catchment approach including the need for transboundary cooperation on prevention

The so called "catchment approach" to flood risk management may be favoured in the face of climate change to ensure all possible flood hazard reduction measures are taken across the catchment, so as to decrease the pressures on structural flood defences downstream. An explanation of what is meant by the "catchment" approach, and why this approach is beneficial in view of climate change as no-regret options, is given below.

The catchment approach to flood risk management can offer real benefits and advantages to flood risk managers. The catchment approach provides the appropriate spatial unit of management: the basin or sub-basin. The catchment forms the arena for risk and hazard mapping and enables the causes and effects of flooding to be examined and linked. This, in turn, helps identify where and how floods arise and have their impacts. Ultimately, this supports the identification and selection of measures for reducing flood risk to people and business and the environment.

For example, river flooding may occur in communities because of a combination of local and upstream factors. By identifying and describing the flood processes within the catchment, these factors can be revealed. Examples of measures that can be combined to reduce flood risk included planning to avoid flood risk areas; building flood resilient properties; better flood warning systems; soft and hard engineering in highly urbanised areas; natural flood management techniques such as wetland

restoration and renaturalisation of river flows; sustainable urban drainage schemes and at-risk property removal.

The process is particularly suitable for climate change adaptation measures and water resource management plans, both strongly linked to economic, social and environmental sustainability. For example, some flood risk management is likely to consider natural flood management, i.e. the restoration of natural features of the environment that contribute to storing or slowing flood waters. Several of these measures, such as the reconnection of rivers to flood plains or the restoration of wetlands, slow the flow of water downstream and lead to a more natural flow regime within a catchment. In addition to the flood risk benefits, these approaches can deliver a wide range of environmental and biodiversity benefits, assist the climate change adaptation agenda, contribute to electricity production from hydro developments and support industries reliant on a regular supply of clean water.

By improving understanding of flooding processes and the links between rural and urban areas, as well as those between neighbouring and distant member states, a catchment approach can help direct resources to cost effective options so as to reduce flood risk, which can also have the potential to deliver a wide range of coincident benefits.

Guiding principle:

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).

Ensure land use / spatial planning is robust in view of climate change

In view of climate change, more efforts are needed to ensure flood risk is considered in spatial planning and in other local land use management. Locating a new housing project close to a lake or river which is likely to become flooded even more often in the future may not be a way of reducing potential flood damage in the future, and it may be very costly. Such decisions are taken today, and even if the increased floods of increased sea/water levels are not a threat today, the project is clearly supposed to be located at that place also in 2050 or 2080, when climate change is expected to have more severe effects. Relocation of such assets at a later date may not necessarily be a cost-effective option. Likewise, the decision on whether to give more room to the river (by moving dykes for instance) instead of increasing the height of a dyke - which also involves a land use decision - is a measure with a long expected life time. Also in the shorter run, if building in a flood-prone area cannot be avoided, then the importance of building flood resilient buildings in such an area is an example of a measure with long term effects.

It is therefore crucial that flood risk management and spatial planning should even today closely take into account climate change scenarios, and for these links to be legally strengthened. Flood Risk Management Plans shall furthermore take into account spatial planning and land use, and may include promotion of sustainable land use practices.

Member States may include measures towards this aim in the FRMPs:

- MS may include changes or clarifications of the legal situation regarding building in flood-prone areas (in some cases stronger legislative basis for spatial planning),
- New buildings or new infrastructure should be built so that already built-up areas will be safer and protected against floods.
- Considerations of moving assets (economic, humans, critical infrastructure…) away from high flood risk areas – relocation.

Short-term vs. long-term considerations in cost-benefit assessment

Identifying long-term changes in the climate patterns now can help prevent that "regret decisions" are taken that will increase vulnerability in the future. These actions will benefit in the long-term perspective. One example is land-use decisions (see above).

When taking climate change into account in the consideration of measures, it is also important to consider the uncertainty associated with climate change objectives, and also the temporal planning of measures (i.e., sequenced projections of measures to be implemented over time).

This is also the case when carrying out cost-benefit assessment for flood risk management measures. It is furthermore important to properly take into account (and evaluate) the long term costs and benefits, and not just consider the short term, especially since benefits will be long term but costs short term. An important example relates to loss of agricultural land, where the benefits to society of long-term food security should be included rather than simply using the market (private) value of land.

Use of economic incentives

Risk awareness can be increased with the help of economic instruments, including the use of insurance premiums to send the right incentive price signals regarding the potential flood risk of an individual property in flood zones. Apart from giving an incentive for building in a flood-resilient manner, insurance policies are of course an important instrument at the end of the "safety chain", as they help to restore flood damage. Therefore, the future role of insurance in view of climate change and floods needs to be considered.

Guiding principle

16. Assess other climate change adaptation (and even mitigation) measures on their impact on flood risks

Hydropower and flow regulations

New modifications to water bodies (hydropower dams for instance) may change flood risks and there is a need to coordinate and exchange information between WFD and FD management.

Existing dams can also contribute to flood risk management. This should be recognised in flood risk assessment and management.

Dams and reservoirs, if properly planned and managed, can be considered as an important part of integrated water management schemes under climate change conditions. Multifunctional dams may contribute to water storage (for drinking water supply), flood protection, hydropower, stabilisation of discharge downstream in times of drought for ecological purposes, maintenance of water abstraction and discharge for power plants, navigation, recreation, fishery and nature protection."

Such dams are subject to operation licenses (also called concessions in some countries) for hydropower schemes in which the regulating national authorities establish the conditions under which a power plant shall be operated at different moments of the year and sometimes even of the day. This license/permit contains detailed conditions for river flow regimes and minimum and maximum water levels to respect according to the season, so that for example enough storage space is in the reservoir to absorb the spring flood. The WFD also requires that such permitting regime of impoundments are regularly reviewed.

Storage power plants have an important effect in reducing local floods, but run-off-river power plants can also have a positive effect, especially on smaller and medium flood events. The way the water flows are regulated in such rivers should take potential changed flood patterns into account, to make sure flood risk isn't increased, but rather decrease in the way the flow is managed.

Example 8g: Hydropower in Sweden

In most of the major rivers in Sweden there are cascades of dams and hydro power plants built for electricity production. The dams and the hydropower plants are owned by the electricity producers. Permission for the facilities and for the water regulation is given by environmental courts after a trial where concerned interests are scrutinized and balanced. The power plants are run in cooperation with other dam and other plant owners within the river. A secondary effect of the river regulations has been that floods and inundations occur less frequent, especially in spring time related to snow melt.

A committee, with representatives from authorities and the power and mining industries, has been established with the assignment to study the vulnerability of the existing dams to climate change. Comprehensive work is ongoing with development of methods and analysis of effects on the magnitude of the 100-year flood and the design flood for dams based on data from several regional climate simulations from different European research institutes. The committee work increases the understanding of possible effects on the magnitude of floods in a changing climate as well as the related uncertainties.

Example 8h: Hydropower in Norway

In Norway, regulated rivers often host several dams and power plants which are operated by different owners. The operation license granted by the government for each power plant (including the related dams and dikes) regulates a coordinated flow regime for the whole river basin according to various needs, such as flood mitigation and protection of fish, to ensure safe ice conditions on the river for transport in winter, appropriate water volume in waterfalls for tourists, and so as to keep the fjords as much as possible ice-free. In the context of climate change, the melting glaciers combined with more intensive precipitations in winter increase the risk of winter and spring floods. Increasing the storage capacity of water will hence become a key issue, since the security of electricity supply could be compromised if the reservoir levels have to be kept low in order to absorb winter and spring floods, while people need electricity to heat their houses during the cold winter season, 99 % of which comes from hydropower. Therefore in Norway water management is the responsibility of a special governmental agency, the Norwegian Water Resources and Energy Directorate, which assumes the integration of various water needs into an adequate operation licenses for all hydropower plants.

Example 8i: Managing multifunctional dams

The Czech Republic and Germany are sharing inter alia the transnational Elbe River Basin. As a consequence of the severe flood event in summer 2002, both countries agreed to assess and better integrate the Vltava/ Moldau Dam Cascade and the Dams in Germany into the transnational flood protection scheme as stipulated in the Flood Protection Action Plan of the International Commission for the Protection of the Elbe. The relevant snow melt flood in early spring 2006 bolstered the strategic approach to adaptively manage multifunctional dams in a national and transnational setting.

Link with water scarcity

For those areas where the hydrological regime might become more irregular and for which therefore more extreme droughts and floods are expected, two opposed responses can follow: volume increase of retained water resources behind dams to reduce drought severity, and greater free volume available behind dams to reduce flood discharges. Reservoir safety and management will in these situations require further attention.

Specific attention to this is therefore needed in flood risk management plans, including in different awareness-raising and preparedness measures.

Suggested actions

- Further development and exchange of good practices on adaptation measures related to flood management.
- Ensure land use / spatial planning is robust in view of climate change.
- Improve economic models to enable taking into account long-term costs and benefits in planning.
- Increased use of economic incentives, such as the cost of insurance being linked to flood risk of individual properties.
- Review permits for impoundments (see WFD) to make sure possible climate change related flood risks can be mitigated.
- Consider occurrence of multiple hazards in flood risk management, example of increased incidents of ephemeral floods.
- Develop tool-boxes and examples of "no-regret" and "win-win" measures, and exchange this information across the EU.

8.4.4 Links to WFD

Guiding principles

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

WFD Art 4.7 New modifications

As mentioned in chapters 7 and 7.7 of this Guidance, the implementation of specific adaptation measures, for instance infrastructure projects, might invoke WFD Article 4(7) (exemption for new modifications) more often in the view of climate change. Article 4(7) requires the identification and consideration of alternatives, i.e. "significantly better environmental options".

Proper consideration of the possible impact of climate change in the implementation of the Floods Directive will benefit the application of these objectives. The Flood Risk Management Plans should make reference to the application of these provisions in the WFD, in view of the need to take into account the environmental objectives in the FRMP (Art. 7, FD).

WFD Art 4.6 Temporary deterioration

The Guidance Document No. 20 on Exemptions to Environmental Objectives states that „It is most likely that "extreme flood" events falling under category (a)[low probability or extreme events] will require the application of a 'temporary deterioration'. However, floods with a higher probability of occurrence may also be regarded as "extreme floods" in circumstances where the impacts of such floods are equally exceptional or reasonably unforeseen."

What is an "exception flood" may change as a result of climate change, and flood risk managers must anticipate more extreme events. When use is made of article 4.6 to justify temporary deterioration of status following a flood event, it is therefore important that all required conditions of article 4.6(WFD) are complied with, and that the implementation of the Floods Directive takes into account climate change in a way that facilitates the compliance with these provisions. As agreed by Water Directors in the same Guidance document, "In no way does the application of exemptions under the WFD give a Member State a possibility to make an exemption from the obligation of implementing all aspects of the Directive on the assessment and management of flood risks."

Further guidance on what constitutes exceptional floods in the context of climate change, changing the patterns of floods as regards location, intensity, and duration may be developed, as well as a practical guidance on how to comply with the conditions set out in article 4.6 as regards for instance taking all practicable steps to avoid further deterioration.

The Flood Risk Management Plans shall make reference to the application of these provisions in the WFD, in view of the need of taking into account the environmental objectives in the FRMP (Art. 7, FD).

Protected areas and drinking water abstraction areas (WFD Articles 6-7)

The WFD protected areas are indicators in the Floods Directive for environmental impacts, and need to be considered in mapping and planning. The relevance for climate change is the effect of more frequent flooding or flooding over longer periods of time of drinking water abstraction areas. It is therefore recommended that the FRMP includes measures such as:

- Increased incidents of high probability floods could help cleaning up; however the normally beneficial effects of flood could be reduced. There are uncertainties on the effects which need to be considered in flood risk management plans.
- There may however be a higher likelihood of contamination due to flood events of water bodies used for drinking water abstraction; , the safety and availability of drinking water needs to be taken into account in FRMP. Subsequently, more resilience needed against negative effects of floods is needed with climate change.
- There is also a higher likelihood of contamination of ready-to-eat fruit and vegetable crops, both directly from flooding and indirectly from less extreme events which cause contamination of irrigation water, due to increased sewer overflows for example.
- This is a learning process and this issue needs to be addressed in particular in the update of plans.

How to deal with uncertainties of flood risks needs to be fully taken into account when managing the protected areas and a process of joint/holistic management needs to be built, involving both water quality and flood risk managers.

Suggested actions

- Take into account guidance and expertise on catchment approach and non-structural measures when investigating "better environmental options" according to Art 4.7 WFD.
- Include information on exceptional floods giving rise to the use of Art 4.6 WFD, which is consistent and coherent with the information and measures included in FRMP.

9 DROUGHT MANAGEMENT AND WATER SCARCITY AND ADAPTATION

9.1 Introduction

This chapter deals with addressing specific effects of climate change in areas exposed to water scarcity and drought. In these regions, water is an essential and scarce resource. Many economic sectors are strongly dependent on water availability, and therefore a major challenge of water management is to balance water supply[42] and demand; this challenge will be aggravated by climate change.

Water scarcity and drought have been broadly documented as phenomena which are likely to be impacted by climate change in European countries (EC 2007a, IPCC 2008, EEA 2008), but climate change is only one of many pressures which must be faced by water management in these areas. If climate change produces a further reduction of water availability, the impacts in these regions may be very strong; therefore special consideration should be given to include climate change in hydrological planning.

As explained in chapter 4, an official Communication was issued regarding water scarcity and droughts (EC 2007b), which is one of the bases for the guidance provided in this chapter. As well as being in the focus of policy, water scarcity and droughts are also the subject of several European research projects concerning, for instance, management options under water stress (see Annex II).

In order to discuss adaptation in water management, it is essential to differentiate between the terms "drought" and "water scarcity".

The term "**drought**" refers to a temporary deviation from long-term average or normal conditions in a hydrological context with regard to water supply. It usually originates in a considerable reduction in precipitation over a significant period of time and with a substantial spatial extent. Through interconnection within the natural water cycle, changes in other climate or land surface conditions can also cause droughts, e.g. through an increase in ambient air temperature and consequently higher evapotranspiration rates. The propagation of droughts through the water cycle may cause temporary shortages in water supply; their impacts depend on vulnerability and coping capacities on the demand side. Climate change can affect the gradual change of average conditions, as well as the frequency and magnitude of deviations from them, thus affecting the occurrence of drought events.

The term "**water scarcity**" indicates a long-term imbalance of water supply and demand in a region (or in a water supply system) possibly characterized by a semi-arid or arid climate and/or enhanced by a fast increase of water demand, associated with population growth and/or an extension of irrigated agriculture. Climate change may create or intensify water scarcity problems in a region, either through a reduction in water supply or through an increase in water demand.

[42] Water supply refers to the quantity of water generally available and not only to water supply for a specific use, e.g. urban water supply.

9.2 River Basin Management Plans as a tool for addressing water scarcity and droughts

In addition to the guiding principles in the sections below, one overall guiding principle covering drought management, water scarcity and adaptation can be highlighted:

Overall guiding principle

1. Use the Water Framework Directive as the basic methodological framework to achieve climate change adaptation in water-scarce areas and to reduce the impacts of droughts.

Guiding principles

2. Make full use of the Water Framework Directive environmental objectives, e.g. by the requirement to achieve good groundwater quantitative status 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.

The River Basin Management Plans required by the WFD offer considerable potential to address drought consequences and water scarcity issues. This becomes even more valid under a changing climate, in which additional stress is put on water resources.

First of all, the planning process required by the WFD provides the right way of analysing pressures, setting objectives and putting cost-effective measures in place. There are many links between climate change adaptation measures related to water scarcity and droughts and the WFD environmental objectives, such as good groundwater quantitative status, sufficient surface water quantity to sustain ecological status, and also broader objectives such as rational water use. In specific, the WFD requirement to achieve good groundwater quantitative status includes ensuring a balance between abstraction and recharge of groundwater. Also by the requirement of achieving good ecological status for surface waters, a river site-specific minimum flow needs to be established, which sustains the achievement of the site-specific objectives with respect to aquatic life. Measures to achieve these objectives have to be reported in the River Basin Management Plans. Such measures include the economic tools mentioned in Article 9 of the WFD (e.g. water pricing policies providing adequate incentives to use water resources efficiently).

It is recommended to consider the option of developing a specific drought management plan (DMP) to prevent and alleviate drought impacts (see CIS guidance on this topic[43]). The main objective of drought management planning is to minimize the adverse impacts on the

43 http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/scarcity_droughts/version_report_fvpdf/_EN_1.0_&a=d

economy, social life and environment when drought occurs, but also to provide prevention strategies for avoiding those impacts in the first place.

In case of exceptional or unforeseen prolonged droughts, the WFD allows for a temporary deterioration of water status. This should be reported in the river basin management plans, including related measures that will be taken in such situation, as well as restoration measures. Specifically, Article 4.6 of the WFD defines that "Temporary deterioration in the status of bodies of water shall not be in breach of the requirements of this Directive if this is the result of circumstances of natural cause or force majeure which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts, ...", provided that the conditions of Article 4.6 are met including among others taking all practicable steps to prevent further deterioration in status.

In addition, the requirements of the WFD Article 4.7 should be applied to any adaptation measures that modify the physical characteristics of water bodies, especially measures related to the development of new water infrastructure to tackle scarcity in a changing climate (see chapter 7.7.3 for guidance on the application of Article 4.7).

9.3 Monitoring and Detecting Climate Change Effects

Guiding principles

5. Diagnose the causes that led to water scarcity in the past and/or may lead to it in the future.
6. Monitor water demand closely and forecast it, based on improved knowledge about demands and trends.
7. Collect as much high quality information as possible to anticipate changes to 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.

Water scarcity relates to long-term imbalances, hence it is not something that comes and goes and changes fast. Climate change may aggravate existing problems of scarcity and may raise problems that are just below surface (e.g. areas in which the demand/availability balance is close to friction). Water scarcity should therefore be "diagnosed" based on past and future water demands. Given the high degree of uncertainty of climate projections and the relevance of challenges imposed by climate change in semi-arid regions, it is essential that the climate change adaptation process be based on high quality information.

The monitoring of precipitation and its transformation into available resources should be used as starting point for monitoring water scarcity under climate change. In this context, it is also necessary to establish monitoring of water uses as well as monitoring of demand. The early detection of droughts requires an advanced monitoring system based on high-resolution hydrometric networks and a system of objective indicators.

The hydrometric networks will have to be adapted to track the impact of climate change on water resources (see also guidance on monitoring under the WFD in chapter 7.4). Hydrometric networks were designed primarily to obtain average values and seasonal and interannual variability of precipitation and streamflow series on the assumption of stationarity. Currently, it is difficult to obtain even those average values, given the deep human intervention on the hydrological cycle in water scarce regions. However, it is critical to

identify the impact of climate change on water resources in a natural regime for the gradual establishment of adaptation policies and for monitoring their implementation.

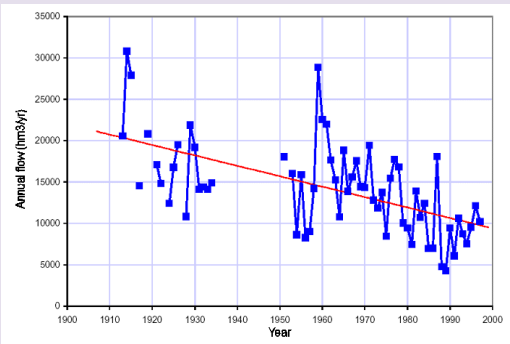
In areas suffering from water scarcity, the balance between demand and supply is already broken. When this current unsustainable balance between water supply and demand is aggravated by climate change, more areas or more catchments will be subject to water scarcity. Therefore, the intensification of monitoring should be accompanied by the development of a comprehensive set of indicators, which can assess the impacts of water scarcity and of eventually increased droughts.

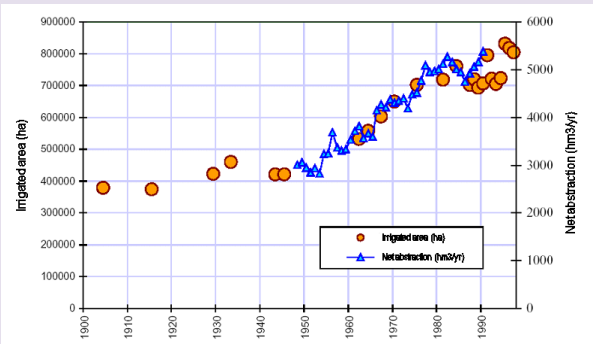
Suggested actions

- Adapt the hydrometric networks to track the impact of climate change on water resources, providing enough redundancy to obtain accurate estimations of naturalised streamflow series from observation, closing the water balance in each subbasin.
- Establish already now a monitoring system of water uses as well as demand monitoring.
- Develop a comprehensive set of indicators at appropriate temporal and spatial scale which can link phenomena in order to predict drought and water scarcity impacts.
- Diagnose water scarcity based on past water demands and improve knowledge about past and current water demands and on future trends, incorporating climate change projections.
- Analyze how predicted changes in mean annual runoff will change supply reliability and how those changes will affect the socioeconomic system behind the water resources system.

Example 9a – Trend detection in the lower Ebro river

The subject of natural flows in the lower Ebro has been one of intense controversy throughout the years. The observed flows at the most downstream station of the Ebro river in Tortosa (figure on the left) show a decreasing trend which has been attributed to climate change. However, the analysis of a series of natural flows obtained through rainfall-runoff modelling, combined with the observed record at Tortosa and the storage fluctuations in the reservoirs allows an estimation of water consumption in the basin, which correlates quite well with the historic development of irrigated areas in the basin as shown in the figure on the right. Only a very dense monitoring network would be able to assess whether a decreasing trend of natural flows in the Ebro river is really occurring.





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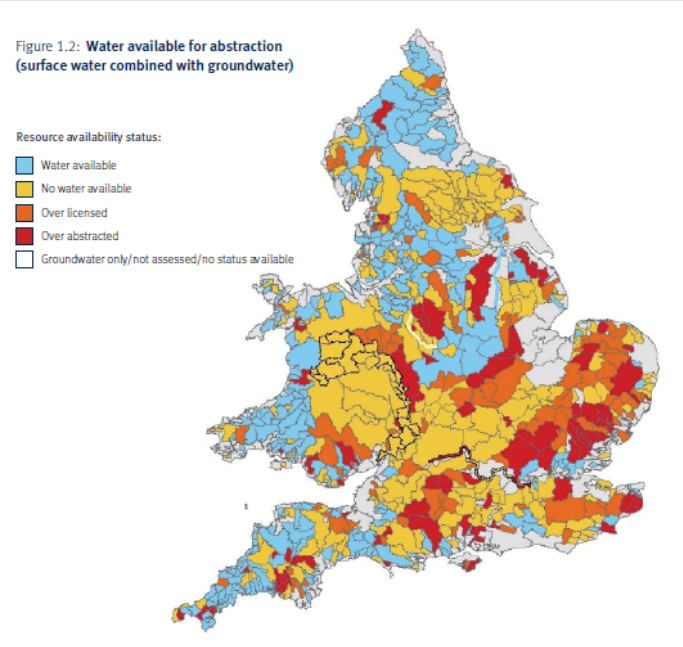
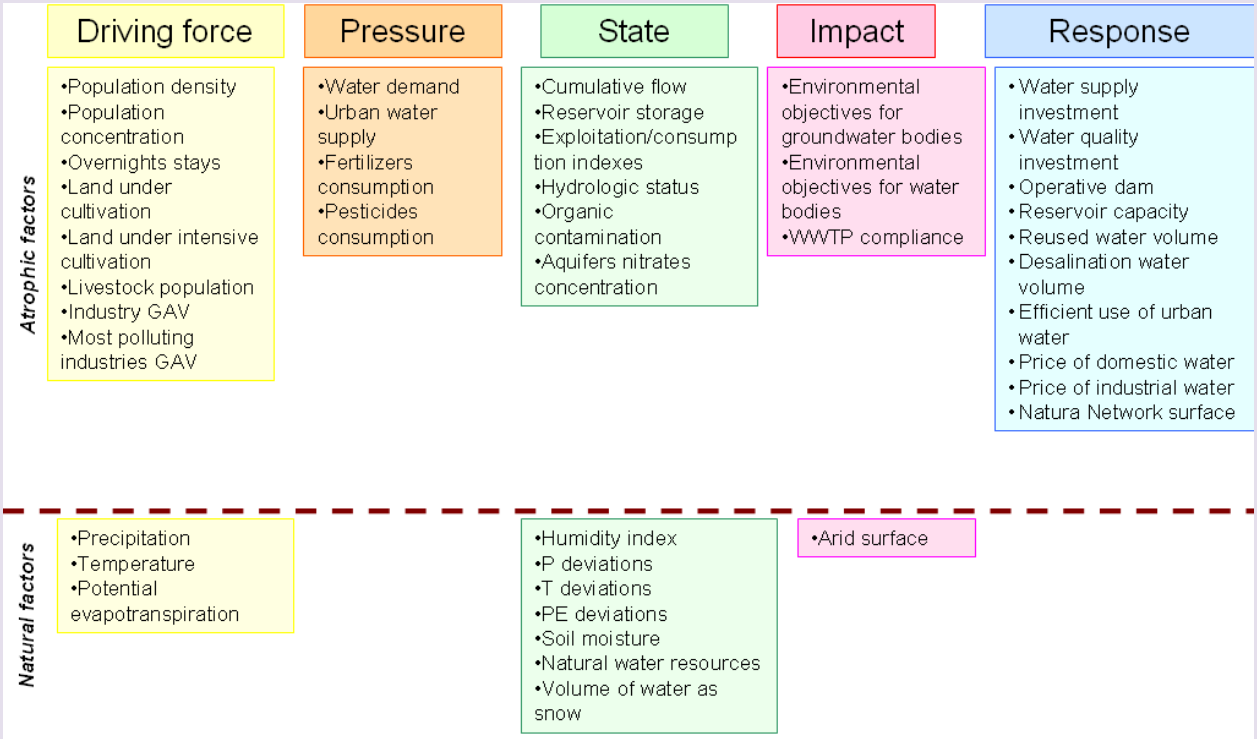
Example 9b – Monitoring of water availability for abstraction developed for the U.K.

We assess the availability of water resources for licensing as part of a programme of Catchment Abstraction Management Strategies (CAMS). CAMS consider the rainfall reliably received, the water requirements of the environment and the amount of water licensed for abstraction. They show us where water is potentially available for abstraction. In 2008, we completed assessments for 119 CAMS, and for the first time, we now have consistent information on potential resource availability on a catchment scale for all of England and Wales (Figure below):



Example 9c – Structure of indicators developed by Spain

The Integrated System for Water Information developed by Spain provides support for the system of drought indicators which are used to detect and declare risk of water shortage in water supply systems. The figure below shows the complexity of the structure of the system of indicators, which combines natural and anthropogenic factors.



9.4 Adaptation measures related to water scarcity & droughts

Guiding principles

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 the focus on sustainability (sustainable 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. Involve stakeholders for engagement to realise decisive measures to tackle water scarcity.
14. Assess other climate change adaptation and mitigation measures on their impact on water scarcity and drought risks.

Most problems anticipated as a result of climate change are in fact an aggravation of current structural problems due to already existing imbalances between water supply and demand. Climate change will imply more radical measures than those already necessary without climate change. Climate change adaptation policies are targeted to prevent or correct these

problems, and therefore they will be equally effective in addressing currently existing water management problems. Accordingly, the determined implementation of adaptation strategies will produce beneficial results in a wide range of climate change scenarios. Especially efforts to prevent water scarcity (including actions on water user awareness raising) and to be better prepared to tackle impacts of occurring droughts should be further intensified.

From the viewpoint of the development of the program of measures (POMs) in RBMPs, taking climate change into account in regions with limited natural water availability should lead to an intensification of policies for demand management as a way to more efficient water management. It is important to always keep the long term in perspective. Some solutions which are perceived as adequate for a stationary scenario may not be so in the long term, under climate change effect.

The first option should always be to intensify actions on demand management to reduce pressure on the water supply sources, especially in times of drought. The greatest scope for action is in irrigation demands, which usually account for the largest fraction of total demand in water scarcity regions. The POMs should include the information and education of citizens to promote or impose the use of domestic water-saving techniques and the intensification of programs for avoiding leakage in water distribution networks and reducing public demand. In a scenario of potential reduction of natural resources, supply-enhancement measures could also be used, promoting non-conventional water resources including wastewater recycling. Under the possible changing conditions in climate change scenarios, it is essential to diagnose the causes that led to water scarcity in the past or may lead to it in the future (see section 9.3) and to set up appropriate regulations to restore a sustainable balance. For this task, the use of market-based instruments should be assessed to address problems caused by water scarcity. It is essential to perform an economic assessment of water use and water value, promoting the efficient use of water by installing individual meters and establishing a pricing policy that penalizes excessive water consumption. But most importantly, monitoring of demand is needed to inform the decisions on supply measures versus water demand management measures.

Suggested actions

- Use the social awareness of the climate change problem as an opportunity to identify the best solution to current challenges in the management of water resources and to correct major environmental problems
- Continue with the options proposed in the Communication on WS&D of 2007: putting the right price tag on water, allocating water and water-related funding more efficiently, improving drought risk management, considering additional water supply infrastructures, fostering water efficient technologies and practices, fostering the emergence of a water-saving culture in Europe, improving knowledge and data collection, etc.

Climate change adaptation will require the progressive reduction of water consumption and the reallocation of water availability to those uses that are deemed socially as more appropriate. These changes cannot be improvised and water managers and decision-makers in water scarcity regions should not wait until the effects are evident to start building adaptive capacity in their river basins (see also chapter 6 for guiding principles on building adaptive capacity).

In a climate change context, the traditional concept of water resources planning should be revised. It will no longer be an activity primarily aimed at increasing the availability of water resources to meet growing demands. **Water resources planning should rather strive to**

develop effective ways of managing the growing scarcity of the resource, mostly through demand management measures.

Moreover, synergies with other fields of water management have to be used more consistently. For example, maintaining certain minimum water flows also under changing (climate) conditions is necessary for both achieving the environmental objectives as well as ensuring the function of rivers as waterways for transportation. Early co-ordination in selecting and planning of adaptation measures could therefore serve both purposes.

Water use efficiency varies tremendously across regions and across different users (i.e. agriculture, households, industry). Some member states already successfully reduced domestic and industrial water use through water-saving policies. Demand management needs to consider that cost-efficiency of additional measures therefore differs for different user groups and regions.

It is also important to enhance the performance of water supply systems by increasing their robustness. Robustness can be built into water resources systems through the expansion and diversification of supply sources and their integration in combined systems. The sources of water supply from different origin can have very different characteristics. Resources of different nature (e.g. surface and groundwater) show highly significant differences in terms of variability and reliability. Even the same kind of resources (such as the regulation of surface water), but for different locations, will show the logic differences in terms of hydrological conditions on each site and the characteristics of their hydraulic systems. Systems that integrate a large number of supply sources can best respond to situations of scarcity through integrated water resources management, using every resource for the purposes that is more appropriate depending on its amount, regularity and reliability. The integration of different kinds of water demands in conjunctive systems allows the satisfaction of the most important demands through the use of strategic reserves or the exchange of water rights. In the long term, investment in improving the performance of water supply systems delivers adaptation benefits.

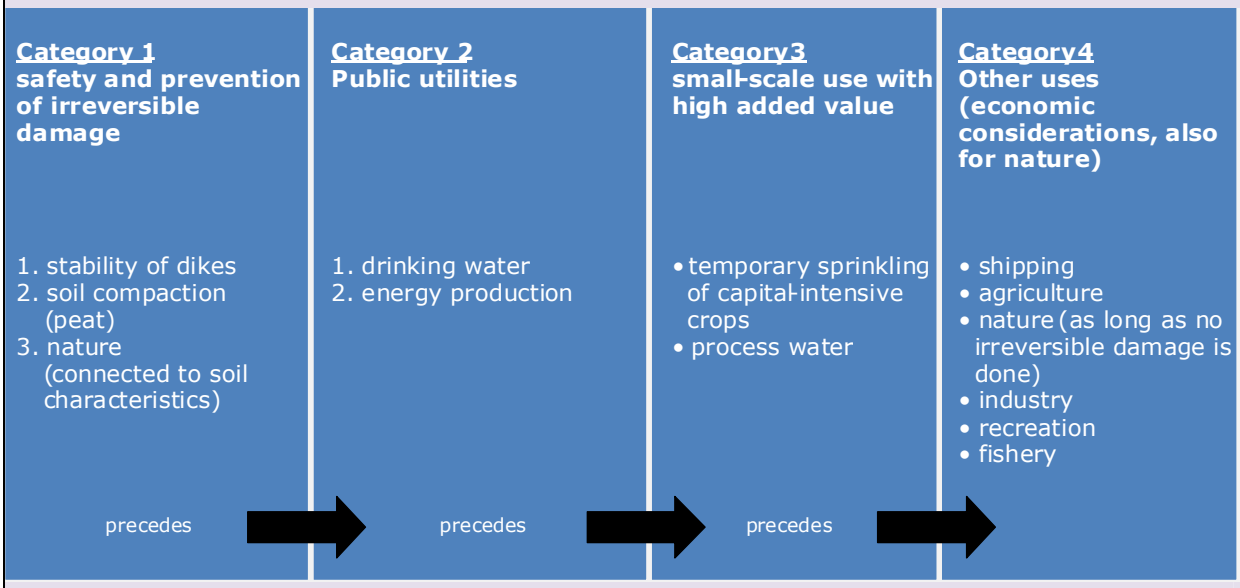
Suggested actions

- Strengthen the institutions in charge of water management to prepare them for the challenges that lay ahead. If necessary, adjust their role from traditional water supply to water demand management
- Build robustness into your water resources system by integrating multiple sources of supply and water demands in conjunctive systems and by improving and enlarging water transportation and distribution infrastructure to achieve the best possible allocation of available resources in future water markets
- Discuss adaptation measures related to water scarcity and droughts in a transboundary and interdisciplinary context

Example 9d: Two-track approach for sustainable freshwater supply in the Netherlands

Existing freshwater supply agreements in the Netherlands will remain in force until 2015. Under normal circumstances, policy is geared towards meeting users' needs wherever possible; as yet, no big problems are expected until 2015, again under normal circumstances. In periods of water shortages (in warm and dry summers), water will be distributed on the basis of the list of priorities and the damage to be contained.
In the planning period 2009 - 2015, the central government will be making long-term decisions on freshwater supplies and salinisation control, including any infrastructure measures and land use

planning this may require (see chart below). In the coming planning period, possible solution strategies are to be worked out with the regions. The key aspects of this new strategy are greater levels of regional self-sufficiency and optimisation of the freshwater distribution in the main and regional water systems. For this too, the central government, the regions and the users will be hammering out solutions in the coming planning period. With the help of long term scenarios, it will be investigated what can be achieved with current policy. In case of a tipping point, a broad range of possible measures is looked at, including moving specific functions as agriculture or nature to water abundant areas. Solutions and areas will be considered as a cohesive whole and the (spatial) consequences for regional systems and functions (drinking water, agriculture, nature and shipping) made transparent.



Example 9e: Successful water demand management in Germany

Domestic drinking water use has been reduced by about 30% in Germany since the 1980ies due to changes in consumer behaviour and technological innovations. This was realized through a combination of various factors:

- A number of studies on future water demand published in the 1970ies predicted a tremendous increase in water use for the upcoming decades
- This information was acknowledged by a growing public concern about environmental issues during the 1980ies
- In a lose but nevertheless close interaction different actors, i.e. governmental bodies and public authorities, NGOs and water utilities promoted water saving and provided consumers with information about water saving
- A water-saving culture became part of day-to-day life and changed people's habits ranging from lawn watering and rainwater harvesting to tooth brushing.
- Obligatory water meters and water pricing according to consumption were already in place, forming water-saving incentives for private households.
- Manufacturers responded quickly with water-saving innovations for washing machines, dish washers, toilet flushers, shower taps, etc.

Meanwhile, the success of water saving causes extra costs and efforts in drinking water supply and

wastewater disposal, e.g. for additional disinfection in case of longer residence times of drinking water in mains, more frequent flushing of sewers, or increased treatment efforts in case of higher concentrations of wastewater contaminants.

Annex I: Adaptation actions/measures – Sources of information

The evidence base for adaptation is not wide, as work on adaptation is still at an early stage. However, with the establishment of national adaptation strategies and in many cases webportals on climate change adaptation, there is a increasing amount of information and case studies that may be used for establishing an overview of relevant adaption actions/measures for the specific RBD and the specific pressures.

There is a number of inventory gathering adaptation case studies and to some extent describing the experience with implementation:

- **EEA and its Topic Centre on Water** have in 2008 and 2009 worked on a report describing good practice examples in relation to adaption to water management (to be published in the second half of 2009). The report's main objective is to compile examples of measures/actions that are relevant for WFD purposes and that can be considered good-practice for adaptation to climate change. It aims to support the efforts of incorporate climate change aspects into their river basin management planning.
- Other **databases for adaptation measures** and concepts are:
  - UNFCC Database of submissions on adaptation planning and practices under the Nairobi work programme: The database provides a query mask to select measures according to country, geographical scale, sector and type of measure http://maindb.unfccc.int/public/adaptation_planning/
  - AMICA-CLIMATE is a European Interreg IIIC initiative which has tried to make the adaptation process more transparent http://www.amica-climate.net/online_tool.html
  - UKCIP Adaptation action case studies. National approach which is a good example of hands-on guidance to become active http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=286&Itemid=423

Adaptation tools and Decision Support Systems (DSS) available online (examples):

- Adaptation toolkit for local councils: "Developing a local authority Climate Change Action Plan": http://www.energysavingtrust.org.uk/scotland/Scotland/Local-authorities-housing-building-professionals/Developing-a-local-authority-Climate-Change-Action-Plan
- Communication strategies for CC: http://www.sustainable-scotland.net/climatechange/index.asp?pg=8

Annex II: Summary of information resources and relevant research

EXAMPLES OF INFORMATION NETWORKS IN EUROPE

This section gives indications to those with river basin management responsibilities on key sources of further guidance and further information concerning adaptation to climate change in Europe, especially with regard to water issues.

Common Implementation Strategy of the WFD (WFD-CIS)

The European Commission and Member States established a Strategic Steering Group (SSG) on Climate Change and Water under the Common Implementation Strategy. The SSG convened in Sep 2007 for the first time. Since then it aimed at integrating adaptation to climate change into the WFD implementation process. The guidance at hand is a product of the preparatory work of the SSG.

UNECE

The United Nations Economic Commission for Europe established a Task Force on Water and Climate under the Convention on the Protection and Use of Transboundary Water courses and International Lakes. The Task Force produced Guidance on Water and Climate Adaptation[44] for decision makers and water managers, in particular at the transboundary level. The Guidance provides a framework to develop step-by-step an adaptation strategy taking into account usual barriers. It provides also an overview of potential adaptation measures. In addition, a Task Force on Extreme Weather Events has been established, which prepares Guidelines on Water Supply and Sanitation in Extreme Weather Events (more concrete and deals with extreme weather events due to Climate Change and their impact on drinking water supply and waste water treatment).

EWP

The European Water Partnership (EWP) is in the process of setting up a European Dialogue on Climate Change Adaptation and Water[45]. This Dialogue will focus on raising awareness, exchanging experiences and best practices between all stakeholders and the set up of concrete projects to help make sure Europe is safe of climate change. It will be a focal point for coordination in Europe, as well as towards the outside world.

Clearing House

The European Commission is for the moment exploring the possibilities of establishing a Clearinghouse on climate impacts and adaptation. The aim is to develop both the software and information architecture for a planned repository ('Clearinghouse') on adaptation. In the future this clearinghouse could be one of the major sources of information on adaptation measures.

ADAM Digital Compendium on Adaptation

This Digital Compendium[46] acts as a portal for the dissemination of the transdisciplinary analysis results carried out in the EU ADAM project[47] (see also section on relevant research

[44] http://www.unece.org/env/water/water.and.climate.htm

[45] http://www.ewp.eu/projects/water-and-energy-climate-cca

[46] http://www.digital-compendium.adamproject.eu/

[47] ADAM - Adaptation and Mitigation Strategies: supporting European climate policy. http://www.adamproject.eu/

projects below). It comprises an adaptation catalogue with possible adaptation measures including information on the extent, feasibility, efficiency, and cost effectiveness of these measures. It is accompanied by key messages about what supports and what hinders adaptation together with a set of learning examples, and a macro-economic analysis estimating the monetary effects of climate change and adaptation for different European countries.

RELEVANT RESEARCH PROJECTS

Integrated research on the functioning of climate and on understanding climate change impacts represents a key component of decision-making regarding adaptation and mitigation. This includes studies on the past evolution of the earth and marine system, including polar regions, and prediction of their future evolution including observations, experimental studies and advanced modelling and taking into account the anthropogenic forcing. Scientific outputs are recognised to be essential for the development of effective adaptation and mitigation measures to climate change and its impacts. For examples, advanced climate change models at the global and regional scales are developed and used to better design measures at various scales. In relation to climate change impacts on water, these models enable to study changes in atmospheric composition on all components of the water cycle. Different approaches are being investigated to translate the output from the climate models to the river basin scale, for example to design risk based approaches to tackle climate related hazards such as droughts, storms and floods.

Research on climate change is closely linked to policy developments at EU level as highlighted in the White Paper on adaptation to climate change and on-going discussions about integration of adaptation and mitigation measures in the river basin management planning of the Water Framework Directive. Scientific outputs are also contributing to international policies and debates, in particular through inputs to IPCC assessment reports and UNFCCC documents. In this context, projects of the 6th Framework Programme (2002-2006)[48] and of the on-going 7th Framework Programme (2007-2013)[49] largely contributed to gathering knowledge relevant to climate change adaptation in the context of the WFD river basin management planning. Research areas are exemplified by projects described below (the list is obviously far from being exhaustive – an updated list of projects in support of climate change research is available[50]), highlighting their potential to be linked to policy developments.

Research into climate change scenarios

PRUDENCE and ENSEMBLES projects

Research on climate change scenarios and predictions have been ongoing and expanding in the last few decades. For example, the PRUDENCE project (2001-2004)[51] has provided a series of high-resolution climate change scenarios for 2071-2100, including an analysis of the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. A continuation of this research line is illustrated by the ENSEMBLES

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[48] In particular projects funded under the 'Global Change and Ecosystems' sub-priority

[49] In particular projects funded under the 'Environment (including climate change)' theme

[50] *European Research Framework Programme: Research on climate change, 2009,* European Commission, EUR 23609

[51] Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects - http://prudence.dmi.dk/et

project (2004-2009)[52], which integrates climate change impact studies into an ensemble prediction system, quantifies the uncertainty in long-term predictions of climate change and provides a reliable quantitative risk assessment of long term climate change and its impacts. It includes the production of Regional Climate Scenarios for Impact Assessments and the formulation of very high resolution Regional Climate Model Ensembles for Europe.

STARDEX project

"Statistical and Regional dynamical Downscaling of Extremes for European regions" (STARDEX, 2002-2005)[53] has given a rigorous and systematic inter-comparison and evaluation of statistical, dynamical and statistical-dynamical downscaling methods for the construction of regional scenarios of extremes. The aim was to identify the more robust techniques and used these to produce future scenarios of extremes for European case-study regions for the end of the 21st century. Large progress was made to the vital question as to whether extremes will occur more frequently in the future.

CECILIA project

The FP6 project CECILIA (Central and Eastern Europe Climate Change Impact and Vulnerability Assessment)[54] has as primary mission to improve the understanding of local climate change in Central and Eastern Europe and its impacts into forestry, agriculture, hydrology and air quality. It thus provides detailed regional climate projections (and impact assessments) for Central and Eastern Europe.

CLAVIER project

The FP6 project CLAVIER (CLimate ChAnge and Variability: Impact on Central and Eastern EuRope)[55] aims to make a contribution to successfully coping with climate change challenges, by studying in detail three representative CEE Countries: Hungary, Romania, and Bulgaria.

CIRCA ERA-Net

Climate impact analysis and adaptation response must be informed by a coherent body of research and it is CIRCLE´s prime objective to contribute to such efforts by networking and aligning national research programmes in the 19 CIRCLE partner countries.[56] The Implementation of a European Research Area (ERA) for climate change is CIRCLE's final goal. The objectives include learning from each other, exchange knowledge and experience, planning and most important establishing transnational research programmes and joint calls. There were 3 regional calls: Nordic, Mediterranean, and Mountainous areas.

Research into climate change impacts on the aquatic environment and water cycle

CLIME project

Research on climate change impacts on aquatic ecosystems has already started within the 5th Framework Programme, e.g. the CLIME[57] project developed a suite of methods and models

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[52] ENSEMBLE- based Predictions of Climate Changes and their Impacts - http://www.ensembles-eu.org/

[53] STARDEX (http://www.cru.uea.ac.uk/projects/stardex/)

[54] CECILIA (http://www.cecilia-eu.org/)

[55] CLAVIER (http://www.clavier-eu.org/)

[56] CIRCLE ERA-Net (http://www.circle-era.net/)

[57] CLIME: Climate and Lake Impacts in Europe (http://clime.tkk.fi/)

for improved management of lakes and catchments under future as well as current climatic conditions. The most up-to-date regional climate scenarios, and existing catchment and lake models were used in the project to address issues that were central to the implementation of the Water Framework Directive. Particular attention was paid to two water quality issues that are likely to become increasingly important, namely leaching of highly coloured water from peatland catchments and increased productivity of some lakes and the increasing frequency of algal blooms.

KLIWAS project

With focus on larger central European rivers including the Elbe, Rhine and the Danube, the interdisciplinary research programme KLIWAS[58] started in 2007. It integrates ecological, economical, water quality and water quantity aspects of climate change for rivers and coastal waters which are used as waterways. KLIWAS strictly follows a multi-model-approach. It uses and evaluates all available climate model runs (including those of the EU-FP6-Project ENSEMBLES and new runs provided by the KLIWAS group) as well as different hydrological models in order to provide a reliable basis for the assessment of various adaptation options. With the purpose of model validation and monitoring of climate change effects, historical data bases are extended, too. A model chain is established, which couples climate models to hydrological/oceanographic, hydrodynamical/sedimentological, water quality and ecosystem models. At each step, uncertainty is analysed in detail to assess the level of understanding of the aquatic systems and their sensitivity to low flow, floods and other aspects of "historical" and future climate change. Changes and possible adaptation measures of the waterways are evaluated taking all functions of rivers and coastal waters into account. Thus, various WFD relevant information is provided.

EURO-LIMPACS project

Research to understand and quantify the impact of climate change (CC) on freshwater ecosystems at the catchment scale has been active through the EURO-LIMPACS[59] project, which examined CC interactions with other key drivers and pressures related to aquatic systems at multiple time scales up to secular trends. The project provided a high level of expertise on CC impacts on aquatic ecosystems which is reflected in a Position Paper (addressed to policy-makers) on "Impact of climate change on European freshwater ecosystems: consequences, adaptation and policy". Scientific achievements combined analyses of long term data sets, the reconstruction of past trajectories from sediment archives, experimental approaches in the laboratory and in mesoscosms, model and scenario developments, and the development and testing of Decision Support Systems (DSS). The results from this research are expected to assist in: (1) assessing the potential impacts of global change at the local to regional scales freshwater lakes, rivers and wetlands across the wide range of European climates, geomorphology types, land-use, and human impact; (2) developing a unified system of ecosystem health indicators related to the impact of CC; (3) reviewing the effect of CC on restoration strategies for freshwater ecosystems and (4) understanding the interaction of CC with key water quality problems such as hydromorphological change, eutrophication, acidification, and long range atmospheric transfer of toxic pollutants. A new FP7 project (REFRESH) will follow on from Euro-limpacs

[58] KLIWAS (www.kliwas.de)

[59] http://www.eurolimpacs.ucl.ac.uk

and focus on an assessment of the practical measures that might be taken by managers to mitigate or adapt to the impacts of CC on freshwater ecosystems.

WATCH project

Specific research on climate change impacts on the global water cycle is carried out under the WATCH project[60] which unites different expertises (hydrologists, climatologists, water use experts) to examine the components of the current and future global water cycles, evaluate their uncertainties and clarify the overall vulnerability of global water resources related to the main societal and economic sectors. The project is developing a number of global and regional datasets to facilitate the assessment of changes in the water cycle, including case studies in river basins located in the EU. In parallel a conceptual modelling framework is being developed to provide consistent modelling results and transfer information between scientists and stakeholders. This will include methodologies to handle biases in climate model output and quantify the resulting uncertainties in estimates of future components of the global water cycle. WATCH aims to increase our understanding of drought and large scale flood development and their propagation for the past and future climates through studies at different scales (global, regional, river basin). Five test basins, within Europe, are being used to translate water resources applications from the global water cycle system to river basins.

CIRCE project

The assessment of climate change impacts on water resources is also being studied in focused aquatic environment, e.g. the Mediterranean area through the CIRCE project[61]. In particular, research is carried out to investigate how strongly climate variations induce significant changes in the hydrological cycle, e.g. increasing atmospheric water vapor, chancing precipitation patterns and intensity, and changes in soil moisture and runoff. The project collects data from observations to quantify those changes and to develop a regional climate model able to analyze the conditions in the Mediterranean area. The investigations concern surface water, groundwater, coastal aquifers and the interactions between them. Both water quantity and quality issues are taken into account. The final goal of this project is to produce an assessment (RACCM – Regional Assessment of Climate Change in Mediterranean) to be used to deepen the understanding of the impact of climate change on water resources and to suggest potential adaptation measures.

ACQWA project

A more focused research is reflected by the on-going ACQWA Project[62] which investigates the consequences of climate change in mountain regions where snow and ice is currently an important part of the hydrological cycle. Numerical models are used to predict shifts in water amount by 2050, and how these changes will impact upon socio-economic sector such as energy, tourism and agriculture. There will be focused studies on governance issues and ways of alleviating possible conflicts of interests between economic actors competing for dwindling water resources. Following a first phase of research in the data-rich European Alps, the models and methods will be applied to non-European regions such as the Andes and the Central Asian mountains, where climatic change and changing snow, ice and water resources will be a source of concern but also of opportunity in the future.

CES project

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[60] www.eu-watch.org

[61] http://www.circeproject.eu

[62] Assessing Climate change impacts on the Quantity and quality of Water – www.acqwa.ch

In the Nordic Region a specific research program has been set up to further investigate the risks, potentials and adaptation measures for the renewable energy resources in the context of climate change, the CES standing for Climate and Energy Systems (http://www.os.is/page/ces_forsida). It is including hydropower, wind power, bio-fuels and solar energy and is in many ways a follow up on the Climate and Energy (CE) Nordic-Baltic research project (2003-2006), both funded by Nordic Energy Research (www.nordicenergy.net) and the Nordic energy sector.

The goal of the CES project is to look at climate impacts closer in time and assess the development of the Nordic electricity system for the next 20-30 years. It will address how the conditions for production of renewable energy in the Nordic area might change due to global warming. It will focus on the potential production and the future safety of the production systems as well as uncertainties. The key objectives are summarized as:

- Understanding of the natural variability and predictability of climate and renewable energy systems at different scales in space and time.
- Assessment of the risks due to changes in probabilities and nature of extreme events.
- Assessment of the risks and opportunities due to changes in production of renewable energy.
- Development of guiding principles for decisions under climate variability and change.
- Development of adaptation strategies.
- A structured dialog with stakeholders.

Research into mitigation / adaptation options and costs

AquaStress project

Mitigation / adaptation options to respond to climate change conditions have been developed, tested and evaluated within the AquaStress integrated project[63], leading to the definition of mitigation options exploiting new interfaces between technologies and social approaches, as well as economical and institutional settings. Particular emphasis has been given to methods, tools and guidelines – e.g. for groundwater modeling, groundwater recharge, improved crop policies - to facilitate a holistic approach to manage water supply and water demand. Several lessons can be derived from the AquaStress experience on improved approaches to integrated and participative water management, which is considered fundamental for adaptation to changing conditions.

ADAM project

Adaptation and mitigation strategies in support of European Climate Policy have also been investigated within the framework of the ADAM project[64] which developed long-term policy options / scenarios that could contribute to the EU's 2°C target and targets for adaptation. The project made significant contributions to climate change policy developments through regular policy briefs, highlighting that Green House Gas emissions could be technically reduced in Europe by up to 80% by 2050. This is obviously only indirectly linked to river basin management developments but it has nevertheless consequences on the way integrated water resource management will have to evolve over the forthcoming decades.

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[63] http://www.aquastress.net

[64] ADAM website

NeWater project

Increasing uncertainties due to the accelerating pace and greater dimension of changes (e.g. climatic and demographic changes) and their impact on water resource management have been investigated by the NeWater Integrated project[65]. The central issue of the NeWater project was the requirement for a transition from currently prevailing regimes of river basin water management to more adaptive regimes in the future. NeWater identified several key elements of the water management system, amongst others governance, sectoral integration, information management, and risk mitigation. Research focused on processes of transition of these elements to more adaptive processes of Integrated Water Resources Management (IWRM).Seven river basins (Amudarya, Elbe, Guadiana, Nile, Orange, Rhine and Tisza) were selected as case study areas to establish the link between practical activities and advances in thematic research and tool development. The project has developed a book on Climate Change Adaptation in the Water Sector and twelve publicly available synthesis products which are of direct interest to policy implementation and development, including databases, guidelines on uncertainty in adaptive management, , evaluation of water resources scenarios in the case studies, a guidebook on adaptive water management, etc. All the reports and tools are available on the project webpage.

AQUAMONEY project

Besides the development of mitigation/adaptation strategies, an important element is the economic valuation of identified measures. In this respect, research has contributed to develop scenarios and quantify environmental and resource costs and benefits linked to adaptation to climate change within the framework of the AQUAMONEY project[66].

ClimateCost project

Efforts are being pursued with the recently launched ClimateCost project[67] which builds up on results of AQUAMONEY and ADAM to further develop climate change and socio-economic scenarios with quantification of related costs, including an assessment of physical effects and economic damages of major catastrophic events.

ClimateWater project

Specific inputs for the identification of gaps that would have possible effects on the implementation of the WFD in combating climate impacts on water are being studied by the ClimateWater project[68]. Based on an analysis and synthesis of data on the likely water related climate change impacts, the project will identify adaptation strategies that were developed in Europe and globally for dealing with the CC impacts on water resources and aquatic ecosystems (preventing, eliminating, combating, mitigating). Research needs in the field of 'climate impact on the water cycle and water users' will be identified with special regard to enable the ranking of adaptation action in the light of the magnitude of impact on water resources and the urgency of the action needed.

Scoping report on Climate Change in Inland Waterways

In 2009, the UK's Inland Waterways Advisory Council published a 'scoping report' on how inland waterways in England and Wales can assist in mitigating for and adapting to the

[65] NEWATER: adaptive integrated water resources management - www.newater.info

[66] http://www.aquamoney.ecologic-events.de/

[67] ClimateCost website

[68] ClimateWater – Bridging the gap between adaptation strategies of climate change impacts and European water policies - http://www.climatewater.org

effects of climate change – in particular, greater winter rainfall, drier summers, higher temperatures and more frequent extreme weather events. Secondary effects also examined included adaptation to changes in sediment run-off, transport and accumulation and changes in flora and fauna. The report highlights the most likely impacts of climate change and the potential consequences for inland waterways in England and Wales. It then identifies and assesses a range of potentially appropriate measures through which changes in use of the waterways could contribute to reducing the extent of climate change (mitigation) and management of waterways can be modified to prepare for the anticipated or recorded effects of climate change (adaptation). The report is available at:

http://www.iwac.org.uk/downloads/reports/IWAC_Climate_Change_Inland_Waterways_Apr09.pdf

Research on droughts and water scarcity

XEROCHORE project

Besides research on management options addressed by AquaStress (see above section), specific research needs on droughts are being discussed in the XEROCHORE Support Action[69] which is currently establishing the state of the art of drought related national and regional policies and plans and will lay down a roadmap that will identify research gaps on various drought aspects (climate, hydrology, impacts, management, policy) and steps to take in order to fill them. In particular, support to European Drought Policy will be provided through expert recommendations about impact assessment, policy-making, drought in the context of integrated water resources management and guidance on appropriate responses for stakeholders. The large consortium (over 80 organisations) is closely linked to the European Drought Centre and the CIS Working Group on Water Scarcity and Drought, which has basically led to the development of an internationally recognised exchange platform on drought issues between the research and policy communities. This is strengthened by links established with relevant RTD projects which include drought components, e.g. WATCH, CIRCE, as well as the recently launched MIRAGE project on Intermittent River Management[70]. It is expected that the exchange platform, now established and developed within the XEROCHORE project, will be further strengthened by the European Commission through the clustering of projects dealing with climate change and water security (including drought aspects) from 2010 onward.

European Drought Observatory

The Joint Research Centre of the European Commission is developing a prototype of the European Drought Observatory (EDO) in the frame of the Seventh Framework Programme for Research, Technological Development and Demonstration. EDO will provide information on drought monitoring, detection, forecasting, and assessment in a multi-scale approach, integrating various information systems that provide information on droughts on international, national, regional, and local level in Europe through interoperability arrangements based on INSPIRE principles. EDO will enable a consistent assessment of droughts in Europe, allow for inter-comparison of different methodologies applied throughout the continent, and foster exchange and collaboration among partners in research and application.

Research on floods

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[69] An Exercise to Assess Research Needs and Policy Choices in Areas of Drought, http://www.feem-project.net/xerochore/

[70] Ref. MIRAGE

FLOODsite project

The project most relevant to flood research carried out within the years 2004-2009 at EU level in support of the Flood Directive is certainly the FLOODsite Integrated Project[71]. The project was interdisciplinary integrating expertise from across the environmental and social sciences, as well as technology, spatial planning and management. The notion of 'integrated' flood risk management now goes towards a change of policy from one of flood defence to flood risks being managed, but not eliminated. The project has developed robust methods of flood risk assessment and management and decision support systems which have been largely tested in pilot sites. Regular contacts with the CIS Working Group on Floods have enabled to inform the policy community about progress on flood risk management. Over than 100 research reports are available for public upload on the project website.

FLASH project

Flash flood events and predictive scenarios have been studied by the FLASH[72] project in five countries (Israel, Italy, Greece, Spain and Cyprus) on the basis of the collection and analysis of lightning data and precipitation observations. Research is continuing on how to reduce loss of life and economic damage through the improvement of the preparedness and the operational risk management for flash floods and debris flow generating events as currently undertaken by the IMPRINTS project[73], which also studies how to contribute to sustainable development through reducing damages to the environment. The project will produce methods and tools to be used by emergency agencies and utility companies responsible for the management of these extreme events and associated effects. Impacts of future changes, including climatic, land use and socioeconomic will be analysed in order to provide guidelines for mitigation and adaptation measures.

CRUE ERA-Net

CRUE ERA-Net[74] has also completed 7 projects about "Risk assessment and risk management: effectiveness and efficiency of non-structural flood risk management measures", while a second call is related to flood resilient communities.

Research perspectives

Modelling capabilities should be improved and appropriate tools should be developed to advance the capability to assess climate effects on water resources and uses. New research areas (resulting from the 2009 FP7 call for proposals) will investigate novel observation methods / techniques and modelling and socioeconomic factor analyses to reduce existing uncertainties in climate change impact analysis and to create an integrated quantitative risk and vulnerability assessment tool. In particular, impacts on key strategic sectors such as agriculture and tourism will be investigated as well as macroeconomic implications of water availability in terms of regional income, consumption, investment, trade flows, industrial structure and competitiveness with focus on Southern Europe, North Africa and the Middle East.

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[71] FLOODsite project 'Integrated Flood Risk Analysis and Management Methodologies' - www.floodsite.net

[72] www.flashproject.org

[73] Improving Preparedness and Risk Management for Flash Floods and Debris Flow Events - http://www.imprints-fp7.eu/

[74] CRUE ERA-Net (www.crue-eranet.net)

In terms of perspectives, research should look into the evaluation of climate change adaptation and mitigation measures across multiple water-dependent sectors, and investigate interactions among water and other environmental compartments (sediment, soil, air). At present, scientific information about water-related impacts of climate change is not sufficient, especially with respect to translation of climate model output to river basin scale (matching the scale of the WFD River Basin Management Plans), water quality, aquatic ecosystems and groundwater, including their socio-economic dimensions. Research into climate change impacts on the water cycle from the global to the regional scale is essential to improve the understanding and assessment of key drivers and their interactions, in order to better manage and mitigate risks affecting the water cycle and to reduce uncertainties in policy responses. This also includes research related to disaster risk reduction to improve understanding and modelling of extreme events related to the hydrological cycles at scales that are relevant to decision making (possibly linked to policy).

ANNEX III: Challenges of selected types of floods

The specific challenges of coastal floods and sea level rise

Due to climate change and the resulting sea level rise, the actual probabilities of coastal flooding will increase without additional measures. Compared to many other sources of flooding, the probabilities will remain rather low but the consequences when it happens are enormous. Only in the North Sea region, about 16 million people live behind coastal flood defences. Especially for estuaries, the combined effects of high discharge probability and storm tides at sea are both influenced by climate change. A moderate exceptional storm tide and discharge can lead to really exceptional water levels in estuaries. Such flood events can also have additional effects of changes in salt/fresh water boundaries. Some studies in for instance in Norway, [75]also show that the tsunami risk is also increasing with climate change, as climate change increases risk of landslides which could trigger floods in coastal areas.

To reduce the flood risk in coastal areas, different measures could be considered in the flood risk management plans and an adapted approach to coastal flood risk management may be required. Issues that may need more consideration are::

- Non-structural (spatial planning) measures like restrictions for new developments in coastal flood-prone lowlands and building regulations to reduce the vulnerability against flooding Multifunctional uses of flood defences (e.g., the Dutch "Delta-Dike-Approach")
- Not "black/white" solutions, but important trade-off and balances of objectives to be found
- Win/win areas for instance for industrial activities to be sought
- Relocation of highly vulnerable activities.

Dealing with flash floods, torrent floods, debris flows and land slides/erosion due to floods

The 4th IPCC assessment report predicts that climate change will increase the occurrence of flash floods across the EU. This leads to a number of new challenges to flood risk management. For instance different or reinforced protective measures against sediment and debris deposits may be needed. Flash floods can rapidly change river flows and debris flows. Those very dynamic hydromorphological processes are well known in the alpine catchments. But as these processes are difficult to foresee on the one hand and may cause major damages on the other hand, they are complicating flood risk management. Flash floods with debris flow and sediment deposits may change river course permanently or temporarily, which will have an impact on hydromorphological condition of rivers and lakes. In practice there may not be any boundary between torrential flood (usually transporting solid material), debris flows and land slides as far as risk management is concerned. The above mentioned increases risk of landslides which could trigger tsunamis. This is another issue which may require attention (see also information on research related to flash floods in Annex II).

Measures that should be included in the flood risk management plans:

- Reinforced awareness raising among politicians of land slide hazards
- Identification of flash floods "hot spots" such as fans (alluvial fans, dejection cones, etc), and rapid changes in plan view of active channels (avulsions and sediment deposition or erosion related processes) to raise awareness of flood risk managements and land use planners.

Urban floods

[76] Olsson, J., Berggren, K., Olofsson, M. *et al.* (2009). Applying climate model precipitation scenarios for urban hydrological assessment: A case study in Kalmar City, Sweden. *Atmospheric Research.* 92: 364-375

It is broadly recognised that climate change will result in an increase in peak rainfall intensities and the frequency with which high intensity rainfall events will occur. Heavy rain and snow induced by climate change could cause significant damage in urban areas. A recent model study estimates the impact on a Swedish city and suggests there could be an increase in the number of surface floods by 25-45 percent during this century. There may also be a non-linear response increase of precipitation vs increase in surface run-off (see example introduction chapter9). If this rainfall is combined with thunderstorms, additional problems such as electrical failures could worsen the consequences because pumping facilities may stop. For example, low intensity rainfall events would cause no direct harm to the urban drainage system. However, they may worsen the effect of events that follow due to saturation of the area. Very high intensity and extreme rainfall events would be likely to cause increased basement floods and surface floods, as well as sewer overflow. The prediction of future flooding could help its implementation, particularly in urban areas where risks are higher. [76]

The impact of increased surface water flood risk in urban areas is likely to be compounded by urban creep (which results in faster runoff from impermeable areas and less infiltration) and the increasing value of the assets likely to be affected. Techniques to enable the identification of areas susceptible to 'pluvial' flooding are evolving as well as management approaches to deal with surface water flood risk but awareness of the potential problem needs to be raised across Member States underpinned for instance by guidance on appropriate responses.

Surface water flooding can also occur in conjunction with fluvial or tidal flooding affecting urban areas and the risk of these types of flooding is also likely to increase with climate change. It is therefore necessary to try to **identify the different sources of likely flood risk in any urban area and their likely interaction**. Such an understanding of flooding mechanisms is often the key to identifying appropriate and cost-effective solutions.

Flood risk management of urban floods should include taking climate change projections into account when identifying where urban water systems have a low capacity and identifying their most vulnerable locations. To manage urban floods in view of climate change, specific consideration are required in relation to the design and dimensions of water run off systems, and management of reservoirs and infrastructure such as underground parkings.

Suggested actions

- Assessment of the likely variation in projected increase in peak rainfall intensity across Member States due to climate change.
- Recognition of the potential significance of surface water flooding in urban areas in terms of damage potential and risk to life to promote awareness raising within Member States.
- Guidance or examples of good practice on appropriate techniques to assess the significance of surface water flood risk in conjunction with other flood risks together with guidance on possible approaches to surface water management in urban areas.
- Further information exchange on examples of "no-regret" or "win-win" measures in view of Climate Change between Member States and internationally.

Annex IV: Definitions of projections, forecasts and scenarios

"Climate Projection" means the calculation of the future climate by means of a climate model, where assumptions about the future development of the greenhouse-relevant emissions – the so called "emission scenarios" (emission of greenhouse gases) – are used at each time step as forcing.

When a projection could be branded "most likely" it would become a **"forecast or prediction"** (according to IPCC[77]). However, as current climate projections are based on hypotheses of future GHG emissions and also because the climate system's behaviour is not sufficiently well known, it is not possible to assign a high level of confidence to projections. Thus, contrary to weather forecast, the term "forecast" is not used for climate simulations.

As it is virtually impossible to foresee the exact development of climate and land use for a longer time, scenarios are often used to assess several possible future outcomes. A **"Climate Scenario"** is defined (also according to IPCC) as "a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold. A projection may serve as the raw material for a scenario, but scenarios often require additional information […]. A set of scenarios is often adopted to reflect, as well as possible, the range of uncertainty in projections." Thus, the definition of a scenario includes the steps of (1) evaluation of uncertainty and (2) a deliberate decision about what "futures" are assumed in a study.

Scenarios may be derived from projections, but are often based on additional information from other sources." An important point is the clear distinction between scenarios and forecasts. Scenarios cannot predict the exact temperature or the water demand for a specific day in the future. They can, however, help to estimate how the mean behaviour of a system may change under certain circumstances.

Nowadays the so-called SRES Emission Scenarios (Special Report on Emissions Scenarios) presented by the IPCC are primarily used as a basis for the climate scenarios. They comprise a total of three scenario families (see box below) providing an assessment of the future emission development and of the resulting greenhouse gas concentrations. Here the difference is basically made between the economic and demographic development and the degree of globalisation. The impacts of political agreements to limit climate-relevant trace gas emissions (such as the Kyoto Protocol) are not considered in the scenario calculations.

A1: The *A1 scenario family* (divided into the scenarios A1FI, A1T and A1B on the basis of the ratio of fossil energies used) assumes a faster economic growth and a rather homogenous world with increasing cultural and social contacts between the different regions of the world. Differences in the per capita income reduce more and more, and the technological development progress is fast and efficient. The global population will peak in the middle of the current century.

A2: The *A2 scenarios* describe a very heterogeneous world oriented towards economy. Population growth continues at undiminished speed, and per capita incomes converge only in some regions and only at a very slow pace.

B1: Like the A1 family, the *B1 scenarios* anticipate fast globalisation, albeit under the

[77] http://www.ipcc-data.org/ddc_definitions.html

assumption of economic structures transforming into a service and information technology oriented society. Here, an extensive introduction of clean and resource-efficient technologies is relevant for the evolution of greenhouse gas concentrations.

Annex V: Member State local climate projections

Below web links to local climate projections of some Member States are provided

Member State	Links to Member State local climate projections
Belgium	Climate projections for Flanders (in framework of Environment Outlook Flanders 2009) http://www.environmentflanders.be (available December 2009)
Germany	http://cera-www.dkrz.de/WDCC/ui/Index.jsp The CERA database includes (among others) data from regional dynamical and statistical downscaling.
The Netherlands	http://www.knmi.nl/research/climate_services/ http://www.knmi.nl/climatescenarios/documents/WR23mei2006.pdf http://www.knmi.nl/climatescenarios/documents/KNMI_2009_EN.pdf For the Rhine currently the project Rheinblick2050: http://www.chr-khr.org/en/projects/rheinblick2050
UK	http://ukclimateprojections.defra.gov.uk

Annex VI: Role of the SEA Process in climate change adaptation

Table 4: SEA Process: How climate change should be considered in the process?

Stage A: Setting the context & objectives, establishing the baseline & deciding on the scope. • Describe the current and likely future climate change baseline. • Identify the likely significant problems and constraints caused by climate change • Develop climate change objectives and indicators that take account of future climate change (see below). • Consult with SEA Consultation Bodies such as the Environment Agency on Flood Risk.
Stage B: Developing and refining alternatives and assessing effects • Suggest plan alternatives to deal with key climate change related problems • Assess the effects of plan alternatives on the climate change objectives and indicators • Refer to Strategic Flood Risk Assessment in the Environmental Report • Integrate climate change adaptation into the final plan
Stage C: Preparing the Environmental Report • Explain in the Environmental Report how climate change issues and uncertainty have been identified and managed
Stage D: Consulting on the draft plan or programme and the Environmental Report • Consult authorities responsible for climate change management and others to provide advice on good practice (see Stage A)
Stage E: Monitoring the significant effects of implementing the plan or programme on environment • Monitor if adaptation has been put in place/implemented • Be prepared to respond to any adverse

Table 5: Aspects of climate change - Example Possible Indicators Example Information sources

Climate/weather changes • Sea level • Precipitation • Temperature • River flows (both extremes) • Flood levels in rivers • Extreme events such as heatwaves • Climate change scenarios, scoping studies, sectoral studies • Climate monitoring and predictions • • Land use change, flood risk

Local impacts of climate/ weather changes • Average annual flood incidence/ damage drought orders • No. cases of subsidence • River flows and water quality • • Environment Agency – flood risk maps, river flows, water quality
Adaptation Measures • % developments with Sustainable Urban Drainage Systems (SUDS) • No. or % homes/roads in floodplain • Household water use • • Environment Agency

Annex VII: National adaptation strategies

Member State	NAS adopted	Impacts, vulnerability & adaptation assessments	Links
Austria	(expected in 2011)	Identification of first measures for climate change adaptation in Austria (Identifikation von Handlungsempfehlungen zur Anpassung an den Klimawandel in Österreich) Austrian Climate Research Programme (ACRP) StartClim (national climate research programme)	Information about the Austrian Activities developing the national adaptation strategy http://klimaanpassung.lebensministerium.at Climate Change and Adaption www.klimawandelanpassung.at The Austrian Climate Portal (ACCC) - Klimawandel und Anpassung http://www.accc.gv.at/anpassung1.htm
Belgium	(expected in 2012)	ADAPT-project CCI-HYDR-project	ADAPT-project (integrated decision tool for adaptation measures, Belgian Science Policy) http://dev.ulb.ac.be./ceese/ADAPT/home.php CCI-HYDR-project (CC impacts on hydrological extremes along rivers & urban drainage systems, Belgian Science Policy) www.kuleuven.be/hydr/CCI-HYDR.ht
Bulgaria			Second National Action Plan on Climate Change http://www2.moew.government.bg/recent_doc/international/climate/NAPCC_Final_English.doc
Czech Rep.			Fourth National Communication on the UN Framework Convention on Climate Change / http://www.env.cz/AIS/web-en.nsf/pages/Climate_Change National Allocation Plan of the Czech Republic 2008 - 2012 / National Program to Abate the Climate Change Impacts http://www.env.cz/AIS/web-en.nsf/pages/Climate_Change Project Czech Carbo http://www.usbe.cas.cz/czechcarbo/ National Climate Program of the Czech Republic http://www.chmi.cz/nkp/nkp.html
Denmark	2008		The Danish Climate Adaptation Strategy http://www.kemin.dk/en-US/climateandenergypolicy/dkpolicy/climateadaptationstrategy/Sider/climateadaptationstrategy.aspx Klimatilpasning http://www.klimatilpasning.dk/
Estonia	(expected in 2009)	ASTRA project	Astra Project (Developing Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region) http://www.astra-project.org
Finland	2005	Finland's National Adaptation Strategy FINADAPT project ISTO programme VACCIA project EUROLIMPACS	Finland's National Adaptation Strategy http://www.mmm.fi/attachments/ymparisto/5h0aZ7Iid/Finlands_national_adaptation_srtrategy_julkaisu.pdf FINADAPT http://www.ymparisto.fi/default.asp?contentid=227544&lan=EN ISTO programme: http://www.mmm.fi/en/index/frontpage/ymparisto/ilmastopolitiikka/researchprogrammeonadaptationtoclimatechange.html VACCIA project: www.environment.fi/syke/vaccia EUROLIMPACS: www.environment.fi/syke/euro-limpacs
France	2007	French research programs on climate change: GICC (Management and Impacts of Climate Change), ANR	Stratégie nationale d'adaptation au changement climatique http://www.ecologie.gouv.fr/adaptation-au-changement.html GICC

Member State	NAS adopted	Impacts, vulnerability & adaptation assessments	Links
		(National Agency of Research) A National Observatory of Climate Change Impacts (ONERC), which belongs to the Ministry of Sustainable Development (General Directorate Energy and Climate), has coordinated various studies and publications related to climate change impacts and adaptation. It has driven the elaboration of the NAS (2007) and is responsible for the elaboration of the national CC adaptation plan (2011).	www.gip-ecofor.org/gicc/ ANR http://www.agence-nationale-recherche.fr/AAP-260-CEP.html ONERC http://www.ecologie.gouv.fr/-ONERC-.html
Germany	2008	KomPass Competence Centre; Klimazwei; KLIMZUG KLIWAS -Impacts of climate change on waterways and navigation – options to adapt	German Strategy for Adaptation to Climate Change http://www.bmu.de/english/climate/downloads/doc/42841.php KomPass http://www.anpassung.net/ Klimazwei Research Programme http://www.klimazwei.de/ KLIWAS www.kliwas.de
Greece			Ministry for Environment http://www.minenv.gr/4/41/e4100.html
Hungary	2008	VAHAVA project	National Climate Change Strategy 2008-2025 (adopted in March 2008) http://www.kvvm.hu/cimg/documents/nes080214.pdf
Iceland		VO project	Iceland's Climate Change Strategy http://eng.umhverfisraduneyti.is/media/PDF_skrar/Stefnumorkun_i_loftslagsmalum_enlokagerd.pdf
Ireland		ERTDI programme; CCRP (Climate Change Research Programme)	Ireland National Climate Change Strategy 2007-2012 http://www.environ.ie/en/PublicationsDocuments/FileDownLoad,1861,en.pdf Environmental Protection Agency http://www.epa.ie
Italy			La Conferenza Nazionale sui Cambiamenti Climatici 2007 http://www.conferenzacambiamenticlimatici2007.it/ ISPRA http://www.isprambiente.it/site/en-GB/
Latvia	(expected in 2009)	ASTRA project	Ministry of the Environment http://www.vidm.gov.lv/eng/ Astra Project (Developing Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region) http://www.astra-project.org
Liechten-stein			Energieplanungsbericht 2006 / Vision 2050 http://www.energie.zh.ch/internet/bd/awel/energie/de/themen/energieplanung.htmlde
Lithuania		ASTRA project	Astra Project (Developing Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region) http://www.astra-project.org
Malta			Malta Environment and Planning Authority http://www.mepa.org.mt/environment/index.htm?climate_change/mainpage.htm&1
Nether-lands	2008	Delta committee; ARK Programme; CcSP	Delta committee advice http://www.deltacommissie.com/en/advies Proposed Delta Act and Progamme

Member State	NAS adopted	Impacts, vulnerability & adaptation assessments	Links
		Knowledge for Climate	http://www.verkeerenwaterstaat.nl/english/topics/water/water_and_the_future/delta_committee/ National programme for spatial adaptation to climate change – ARK en:http://www.vrom.nl/pagina.html?id=2706&sp=2&dn=7222 nl:http://vrom.nl/pagina.html?id=2706&sp=2&dn=7502 Knowledge for Climate http://www.knowledgeforclimate.org/
Norway	2008	NORDADAPT project, NORKLIMA project	Klimatilpasning i Norge http://www.regjeringen.no/upload/MD/Vedlegg/Klima/Klimatilpasning/Klimatilpasning_redegjorelse150508.pdf Community Adaptation and Vulnerability in Norway (NORADAPT) http://www.cicero.uio.no/projects/detail.aspx?id=30182&lang=EN
Portugal		SIAM project Portuguese National Adaptation Strategy	Climate Change in Portugal: Scenarios, Impacts, and Adaptation Measures - SIAM www.siam.fc.ul.pt/siam.html Portuguese National Adaptation Strategy (2009) www.maotdr.gov.pt *Note*: Guidelines for a specific strategy on climate change adaptation for the water sector are being prepared and are expected in 2010.
Romania			Ministry Of Environment www.mmediu.ro
Spain	2006	ECCE; Impacts on coastlines	Plan Nacional de Adaptación al Cambio Climático (PNACC) http://www.mma.es/portal/secciones/cambio_climatico/areas_tematicas/impactos_cc/pnacc.htm A Preliminary Assessment of the Impacts in Spain due to the Effect of Climate Change http://www.mma.es/portal/secciones/cambio_climatico/areas_tematicas/impactos_cc/eval_impactos.htm Impactos en la costa española por efecto del cambio climático http://www.mma.es/portal/secciones/cambio_climatico/areas_tematicas/impactos_cc/imp_cost_esp_efec_cc.htm
Sweden	2009	SWECLIM project; SWECIA project; CLIMATOOLS project; Swedish Climate Bill http://www.regeringen.se/content/1/c6/12/27/78/4ce86514.pdf; Sweden facing climate Change en:http://www.sweden.gov.se/content/1/c6/09/60/02/56302ee7.pdf	se:http://www.regeringen.se/sb/d/9434/a/89363 A Coordinated Climate and Energy Policy http://www.regeringen.se/sb/d/11759 Sweden facing climate change - threats and opportunities/Final report from the Commission on Climate and Vulnerability http://www.sweden.gov.se/sb/d/574/a/96002 Swedish regional climate modelling programme – SWECLIM http://mistras.internetborder.se/mistra/english/researchresults/researchprogrammes/completedprogrammes/sweclimswedishregionalclimatemodellingprogramme.4.1eeb37210182cfc0d680007760.html Climate, Impacts and Adaptation – SWECIA http://www.mistra.org/mistra/english/researchresults/researchprogrammes/activeprogrammes/mistrasweciaclimateimpactsandadaptation.4.a791285116833497ab800017356.html Climatools research programme http://www.foi.se/FOI/Templates/ProjectPage____5846.aspx Climate adaptation in the municipality of Sundsvall http://www.sundsvall.se/livsmiljoochnatur/miljoochklimat/forandratklimat/klimatanpassning/klimatanpassasundsvalldagslaget.5.4b51bfdc121be5d407e8000684.html Climate adaptation in Sweden (Swedish Meteorological and Hydrological Institute) http://www.smhi.se/cmp/jsp/polopoly.jsp?d=9315&l=sv http://www.smhi.se/sgn0106/if/rc/modfigures.htm

Member State	NAS adopted	Impacts, vulnerability & adaptation assessments	Links
			http://www.smhi.se/sgn0106/if/rc/RC.htm http://www.smhi.se/cmp/jsp/polopoly.jsp?d=6024&l=en
Switzer-land		OcCC avtivities	Changements climatiques: conséquences en Suisse http://www.bafu.admin.ch/klima/00469/00810/index.html?lang=fr Advisory Body on Climate Change (OcCC) http://www.occc.ch/index_e.html
United Kingdom	2008	UK National Risk Assessment UKCIP studies	Climate Change Act 2008 http://www.opsi.gov.uk/acts/acts2008/pdf/ukpga_20080027_en.pdfUK Climate Impacts Programme (UKCIP) http://www.ukcip.org.uk/ UK Climate Projections http://ukclimateprojections.defra.gov.uk

Note: The information in this table reflects the state-of-play as of October 2009. In case of problems in accessing the indicated webpages, please consult the following webpage for possible updates: http://www.eea.europa.eu/themes/climate/national-adaptation-strategies

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