COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE AND THE FLOODS DIRECTIVE

Guidance document No. 24

RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE - Version 13

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LIST OF ABBREVIATIONS

BWD – Bathing Water Directive

CIS – Common Implementation Strategy

CEMS – Copernicus Emergency Management Service

DMP – Drought Management Plans

DWD – Drinking Water Directive

EEA – European Environment Agency

EIA – Environmental Impact Assessment

EQR – Ecological Quality Ratio

FD – Floods Directive

FHRM – Flood Hazard and Risk Maps

FRMP – Flood Risk Management Plans

GEP/GES – Good Ecological Potential/Good Ecological Status

GHG – Greenhouse Gases

GWD – Ground Water Directive

IPCC – Intergovernmental Panel on Climate Change

JRC – Joint Research Centre

KTM – Key Type of Measure

MS – Member State of the European Union

NBS – Nature-based Solutions

PFRA – Preliminary Flood Risk Assessment

PoM – Programmes of Measures

RAST – Regional Adaptation Support Tool

RBD – River Basin District

RBM – River Basin Management

RBMP – River Basin Management Plans

WFD – Water Framework Directive

EXECUTIVE SUMMARY

INTRODUCTION

1. Europe's fresh, transitional, coastal and marine waters have been affected by centuries of anthropogenic usage as well as by the unintended consequences of changes in land use, water abstraction and pollution. These anthropogenic pressures are exacerbated by the direct and indirect effects of climate variability and change, increasing the challenges associated with achieving and maintaining good status.

2. The purpose of this updated guidance document is to i) update information on climate change impacts on the water cycle and ii) provide tools to help water managers align river basin management (RBM) planning under the **Water Framework Directive** (WFD), the **Floods Directive** (FD) and to manage droughts through climate adaptation planning by describing guiding principles for water management and adaptation. The principles are intentionally broad to be applicable across all Member States (MS) 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.

3. Although climate change is not explicitly included in the text of the WFD, the stepwise and cyclical approach of the RBM planning process is well suited to adaptively manage climate change impacts, building on climate adaptation plans in the member States.

4. More than two decades of experience with the RBMP process demonstrate that **integrated water management** is the best approach to balance available water resources and demands, thus avoiding long-term water scarcity while also managing flood risks, which is specifically addressed by the requirements of the Floods Directive.

5. In 2019, the European Union's **Green Deal** was launched to transform the Union into a modern, resource-efficient, and competitive economy, ensuring no more net emissions of greenhouse gases by 2050, and making Europe the first climate neutral continent. The ambition is to decouple economic growth from resource use while leaving no person and no place behind. As part of the Green Deal, the European Commission adopted a set of legislative proposals[1] to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

6. In 2021, the European Commission adopted its new **EU strategy on adaptation to climate change** as part of the European Green Deal, aiming to intensify efforts to

[1] The legislative proposals of direct relevance to integrated water management are in particular those under the "Biodiversity Strategy 2030", the "Zero Pollution Action Plan" and the "From Farm to Fork" strategies. See also below in section 3.

protect nature, communities, and livelihoods from the unavoidable impacts of climate change. This strategy coincided with the implementation of the European Climate Law which implements the Paris Agreement's objectives.

7. The **European Climate Law** (2021) obliges EU Member States to adopt national and regional climate adaptation strategies which must consider the vulnerabilities of different sectors such as in particular those of the water/soil/food nexus and promote nature-based solutions (NBS). Regular updates to these strategies every five years and the inclusion of updated information in climate adaptation reports are required. The Commission assesses the compliance of national measures with the adaptation plans and makes recommendations for improvement.

8. In March 2024 the EEA published the first ever **European Climate Risk Assessment**, indicating that Europe's climate risks have already reached critical levels and could become catastrophic without urgent and decisive action. Shortly after the publication of the assessment, the European Commission adopted the **Communication on managing climate risks in Europe**.

CLIMATE CHANGE

9. Human-driven increases in atmospheric greenhouse gases (GHG) cause rapid warming across various Earth systems.

10. Without significant emission reductions, global warming of 1.5°C to 2°C will be exceeded this century, already leading to irreversible changes in oceans, ice sheets, and sea levels, exacerbating extreme weather events and water-related risks globally.

11. Compared to pre-industrial levels, the average temperatures have risen by 1.94 to 2.01°C in Europe from 2010-2020, with the warmest years occurring in the past decade. In fact, 2023 was the warmest year on record over more than 100,000 years globally. Europe is the fastest-warming continent; since the 1980s, warming on the continent was about twice the global rate. Extreme heat is becoming increasingly common, exposing a large share of the population to heat stress, particularly in Southern and Western Europe. More intense and frequent weather extremes, including droughts but also floods, are projected, with southern regions particularly vulnerable to extreme heat, water scarcity, and forest fires.

12. Changes in precipitation patterns will reshape waterbodies and may degrade biodiversity through scouring or desiccation. More frequent and more extreme floods can overwhelm urban wastewater systems, increasing nutrient loads and storm overflows. Prolonged droughts reduce the dilution of pollutants in rivers, exacerbating pollution and degrading the soil. Sea level rise threatens coastal regions, leading to salinisation of freshwater sources and submerging tidal marshes, impacting biodiversity and water quality.

13. Increasing water temperatures disrupt aquatic ecosystems, altering nutrient cycles and causing fish kills. Warmer temperatures affect stratification in lakes and coastal waters, reducing oxygen levels and disrupting species phenology. Geochemical processes are affected by temperature, with soil moisture deficit leading to increased nitrogen mineralisation.

14. Climate-related weather extremes in Europe, including floods and storms, have led to approximately €650 billion in losses from 1980 to 2022. With further global warming, these impacts will continue to rise, making bold adaptation action in sectors like agriculture, industry, energy, and waterborne transport a necessity.

WATER AND CLIMATE CHANGE – EU POLICY FRAMEWORK

15. Several existing European Union (EU) policies address water management issues. The most important are the WFD, the FD, the Drinking Water Directive (DWD), Groundwater Directive (GWD) and the Bathing Water Directive (BWD). Collectively, they provide legal instruments for protecting and restoring the water environment.

16. The European Green Deal initiated legislative proposals of direct relevance to integrated water management. These proposals are in particular those under the "Biodiversity Strategy 2030" to restore the broken water cycle and restoring the sponge function of soils and forests, under the "Zero Pollution Action Plan" to reduce pollutions of water and air, and under the "From Farm to Fork" strategy to make conventional agriculture more sustainable. At the time of revising this CIS 24, several of these legislative proceedings had already been closed and achieved important improvements[2], while others will continue during the next mandate of the Commission 2025-2029.[3]

PLANNING FOR ADAPTATION TO CLIMATE CHANGE

17. Resilience is crucial for social-ecological systems and involves withstanding shocks, recovering from, and adapting to present and future stressors. Climate adaptation is key to water system resilience, addressing stressors and fostering stability. Both the

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[2] The revised Drinking Water Directive is applicable since 12.1.2024 and will contribute to increase water conveyance efficiency by reducing leaks, and improving drinking water quality by prohibiting certain substances. The new Water Reuse Regulation is applicable since 26.6.2023 and allows Member States to reuse waste water for irrigation in agriculture subject to strict conditions and strict controls.

[3] A proposed Nature Restoration Law aims a.o. at repairing the broken water cycle and restoring the sponge function of soils and better lateral and longitudinal continuity of rivers. The proposed revision of the Industrial Emissions Directive would also contribute to more water efficiency in the manufacturing sector and extend the directive's scope to large pig and poultry farms. The proposed revision of pollutants in groundwater and surface waters would update Europe's black list in line with latest scientific findings. A proposed soil monitoring law aims at protecting and restoring soils to ensure that they are used sustainably.

guidelines on Member States' Adaptation Strategies and Plans as well as the Regional Adaptation Support Tool (RAST), with a six-step approach, supports developing climate adaptation strategies, including water protection and infrastructure enhancements.

18. Importantly, climate change impacts on water quality and quantity are intertwined with other anthropogenic pressures, like pollution and habitat destruction. Integrating a RAST – type of analysis prior to or within the RBMP processes can help address these challenges comprehensively, ensuring coordinated responses to both climate and human-induced stressors on water systems. These six steps of the RAST consists of:

19. STEP 1: Preparing the ground for adaptation by strengthening adaptive capacity:

- To strengthen the adaptive capacity in water management it is essential to understand the climate risks, collect data, and develop tailored strategies.
- Key actions include establishing financial mechanisms, identifying stakeholders, and fostering cross-sectoral partnerships.
- Integration of climate change impacts into awareness-raising activities and staff training programmes is essential for effective adaptation.

20. STEP 2: Assessing risks and vulnerability to climate change as part of water management planning:

- To analyse current and future climate risks and potential hazards a vulnerability assessment should be implemented, evaluating impacts across sectors, and considering uncertainties.
- This assessment must encompass risks to water resources, ecosystems, community services, and infrastructure, considering various climatic scenarios[4] and uncertainties.
- Collaboration and participation of authorities and stakeholders is essential to ensure the assessment covers all pertinent hazards and evaluates their impacts across sectors.

21. STEP 3: Identifying adaptation options by considering different adaptation pathways:

- There are often many possible ways to respond to climate change. Often a combination of different actions, some of which are taken now and some later, present the best way forward. To identify competing options, and decide on the most effective ones, and their sequencing, it is recommended to develop WFD programmes of measures along climate adaptation pathways.

- Authorities identify sets of potential adaptation pathways addressing climate change consequences and other pressures. The options include structural and non-structural measures like water reuse and land use change.
- Public consultations should support adaptation measure identification under the WFD, including specific measures to address droughts and water scarcity (e.g., strategies, DMPs), and FD, aligning with national/regional climate adaptation strategies for policy coherence.

22. STEP 4 Assessing and selecting adaptation options:

- The assessment and ranking of water management/adaptation options are based on effectiveness, feasibility, costs, and climate-proofing, ensuring alignment with WFD and FD objectives.
- Climate-proofing enhances resilience to climate change impacts while maintaining water management objectives, aiming to avoid maladaptation and unintended consequences. Authorities should strive to avoid maladaptation which occurs when adaptation actions also have negative side-effects or outcomes for the environment, compromising GES/GEP and potentially even increasing CO2 emissions ('Do No Significant Harm' - DNSH - principle).
- Just Resilience focuses on reducing unequal climate risks burdens and ensuring equitable distribution of adaptation benefits, considering gender-specific vulnerabilities and social welfare in the cost-benefit analysis. Meaningful engagement is needed with vulnerable groups to address social vulnerabilities for drought and flood risk management.

23. STEP 5 Implementing adaptation:

- Implementation involves enacting preferred climate adaptation options using a range of instruments such as legal, economic, informational, partnership, and hybrid strategic/planning instruments.
- Mainstreaming water adaptation planning across sectoral policy-making levels is crucial for coherence and synergy, minimising conflicts, and reducing the need for trade-offs.
- Water resilience from the outset of larger infrastructure projects can prevent costly adaptation measures later and contribute to climate mitigation and disaster risk reduction.

24. STEP 6: Monitoring & Evaluation adaptation

- Continuous monitoring and evaluation of climate adaptation and water management planning are vital to track progress, assess outcomes and adjust the plan. It is all the more important for Member States to conduct monitoring of water resources as outlined in the WFD and the FD.

WATER FRAMEWORK DIRECTIVE AND ADAPTATION

25. Building on this six-step approach to climate adaptation planning, climatologists and water managers can identify climate change induced challenges for the resilience of water ecosystems. Critical RBM steps for climate readiness include robust long-term monitoring, understanding climate impacts, and securing funding for measures to achieve the WFD, FD, GWD etc. objectives.

26. Water managers should be able to distinguish climate change pressures from anthropogenic pressures to know which pressures they can influence, and which ones are a direct consequence of climate change. In respect of anthropogenic pressures, Article 5 of the WFD requires MS to regularly review the impact of human activity on the status of surface waters and groundwaters.

    - The evaluation of these pressures on surface water bodies should consider climate impacts and sectoral developments and the integration of future projections into models for comprehensive assessments. The development of adaptation strategies in the RBMPs should be aligned with national climate adaptation plans, including improved measures and NBS to tackle the adverse impact induced by climate change.

    - The assessment of groundwater vulnerability should use models and meteorological criteria, accounting for short- and long-term climate risks, like prolonged droughts. Standardised approaches for attributing changes to climate factors should be developed, aiding robust adaptation planning and WFD implementation.

27. Some types of water bodies may permanently change because of climate change despite additional measures being implemented. If so, these water bodies should be assigned to an appropriate type within the existing typology and the corresponding reference conditions applied to them. If there is no possibility for re-assignment to an existing type, a new type could be created or an existing one updated with its specific reference conditions and class boundaries.

28. The status assessments should be based on transparent criteria and should be supported by robust and long-term monitoring data, to detect water body responses to climate change and to accurately assess the ecological and chemical status considering climate change impacts. Climate change may affect water body typology, for example through altered morphology, hydrology, nutrient or salinity dynamics. Water bodies can

therefore migrate from one type to another because of gradual climate change or a sequence of extreme events.

29. A groundwater status assessment under the WFD considers thresholds, trends, and indicators affected by climate change pressures, with methods outlined in the CIS Guidance Document No 18, emphasising the need to balance natural recharge, avoid alterations detrimental to ecosystems, and address the impacts of sea level rise. Assessment methods vary and can include spring flow measurements, volume calculations, and water balance assessments. In some countries, this assessment will include the consideration of regard ecological needs and the impact of sea level rise, highlighting the importance of ecologists' input in specifying ecological requirements.

30. WFD Article 7 (drinking water abstraction areas) should be considered when addressing climate-related challenges as for current extraction the drinking water standards need to be met and water bodies for future use be secured.

31. The efforts to protect Natura 2000 areas from the impacts of climate change require often improved water management. A combined approach is needed to ensure biodiversity conservation.

32. Another important aspect of climate change adaptation in water management is the appropriate monitoring of trends, as climate change impacts may be noticeable only in longer time series. Long-term surface water and groundwater monitoring can indicate climate change signals and help assess impacts on aquatic ecosystems, however this necessitates careful planning and consistent methodologies. Enhanced monitoring efforts in vulnerable groundwater environments and during extreme events better capture gradual changes in ground- and surface water interactions as well as seasonal variations, providing a robust scientific basis for proactive adaptation strategies.

33. Article 4.4 and 4.5: Exemptions under the WFD should be used sparingly (see also CIS Guidance No. 20) and climate change should only be considered as a valid justification for permanently decreasing objectives where all legal conditions are met based on robust evidence, avoiding reliance solely on modelled assumptions. Long-term analysis and complete evidence-based analysis should guide decisions on accepting less stringent environmental objectives in line with WFD principles, also considering uncertainties of climate projections.

34. Article 4.6: The application of temporary exemptions due to prolonged droughts and extreme floods must equally be based on robust scientific evidence, while distinguishing in particular between droughts and water scarcity. Where climate change exacerbates anthropogenic pressures, anthropogenic pressures should be reduced as a matter of priority.

35. Article 4.7: Adaptation measures for climate change impacts may require heavy modifications to water bodies such as the construction of flood dams. Article 4 (7) WFD allows for such modifications under strict conditions. Repercussions on the ecological status of surface water bodies should always be limited to the minimum necessary for achieving a legitimate objective. Once heavy modifications become inevitable, a good ecological potential should be defined and achieved. Importantly, infrastructure projects necessitating exemptions under Art. 4(7) should also undergo a climate-proofing to avoid maladaptation.

36. Economic analysis in WFD implementation potentially becomes more crucial with changing climatic conditions, requiring an integration of potential climate change impacts and constraints. For instance, assessing measures under multiple climate scenarios can help identify cost-effective options to meet the WFD objectives.

37. Financing adaptation measures for WFD objectives and flood risk mitigation may require substantial investments. Despite financial constraints, diverse funding sources are available, necessitating good knowledge of funding opportunities and their applicability. Cost recovery efforts, guided by WFD Article 9, should account for financial, environmental, and resource costs, aligning with the Polluter-Pays-Principle and ensuring adequate incentives for efficient water use.

38. The WFD necessitates timely and climate-robust measures in RBMPs to achieve environmental objectives, including grey, green, and soft options. Incorporating climate change predictions into the selection of measures in RBMPs should align with the precautionary principle and preventive action. The selection of measures should comply with the precautionary principle and the principles that preventive action should be taken regarding environmental protection (Article 174 of the European Treaty). Changing climatic conditions may require additional measures going beyond basic measures to achieve WFD objectives, particularly addressing hydromorphological or physico-chemical changes, or an increased risk of invasive species due to rising temperatures.

FLOOD RISK MANAGEMENT AND CLIMATE ADAPTATION

39. In the **Preliminary Flood Risk Assessment** (PFRA) the consideration of climate models enhanced the understanding of flood hazard changes due to climate change. However, challenges exist in integrating raw model outputs into flood frequency estimations, necessitating collaboration with national meteorological services for consistent climate projections across various assessment levels. It is prudent to consider future land use changes alongside climate projections. These changes can significantly impact flood flows, necessitating an evaluation of their individual and combined effects on the flood risk. Despite challenges in distinguishing between land use and climate change impacts, their consideration is vital for a comprehensive flood risk assessment.

40. Illustrating changes in flood extent under different climate scenarios in **Flood Hazard and Risk Maps** (FHRM), although not mandatory, would enhance awareness and understanding. Continued development of analytical and cartographic methods is crucial to visualise probabilities and uncertainties, improving flood-mapping accuracy and aiding in climate change adaptation planning.

41. **Flood Risk Management Plans** (FRMP) mandate objectives focusing on mitigating flood consequences and reducing likelihood. Synergies with the WFD and other EU policies ensure holistic risk reduction strategies, considering climate change impacts and integrating environmental objectives. Effective measures should prioritise long-term prevention, robustness to climate uncertainty, community resilience, and stakeholder consultation, following guidance from global institutions like the World Meteorological Organisation (WMO) to incorporate climate projections into planning.

42. Adopting integrated flood management approaches strengthens societal resilience by combining risk management principles with NBS, stakeholder participation, and harmonised water and land management strategies, aligned with the principles of Integrated Flood Management. Public awareness campaigns, digital flood viewers, and educational initiatives enhance flood risk understanding and promote adaptation measures. Improved civil protection measures and multi-hazard disaster preparedness are vital responses to increased climate-induced hazards, ensuring communities are better prepared for future flood events.

DROUGHT MANAGEMENT AND CLIMATE ADAPTATION

43. RBMPs under the WFD can help address **water scarcity** by identifying drivers and pressures, implementing measures to reduce abstraction pressures, promoting efficient use, and demand management. These measures can contribute to drought resilience and preparedness, aligning with the EU's objectives for sustainable water management and environmental protection.

44. **Drought Management Plans** (DMPs) and other similar strategies and tools are recommended alongside (or as an integral part of) RBMPs to manage drought risks more effectively. DMPs should contain at least three elements: (i) Indicators and thresholds to define the beginning, end, and severity of droughts; (ii) measures to be taken in each phase of a drought to prevent deterioration of the water status and to mitigate negative effects; and (iii) an organisational framework with a transparent governance to deal with drought and subsequent revision and updating of the existing DMPs (feedback loop based on analysing drought impacts).

45. Adaptation measures for water scarcity and droughts should prioritise a **water-smart economy**, integrating the management of all water resources to enhance resilience to climate change and mitigate risks. A **cost-effectiveness analysis** should guide the selection of measures, considering socio-economic and climate scenarios, while

avoiding negative externalities like adverse impacts on environmental flows from water reuse practices.

46. Priority **water allocation mechanisms** during water scarcity need to consider climate change risks and uncertainties. They should prioritise essential needs like drinking water and critical infrastructure while maintaining ecological integrity. Flexibility in defining priorities at different governance levels and stakeholder engagement is vital for effective implementation and adaptation to changing conditions.

47. **Efficient water use** and **pricing** policies should incentivise water conservation and reduce wastage. Allocation decisions must balance economic, social, and environmental considerations, ensuring equitable access to water resources while promoting sustainability and resilience against droughts as well as (seasonal) changes in precipitation characteristics. Regular reviews and stakeholder involvement enhance transparency and accountability in water allocation processes.

48. Integrated water management is also much more than water distribution and water treatment, only. It also involves **land-use** and **land-management** that affect both water quality and quantity. Pressures are often interlinked, including both climate change, land use, economic activities (energy production, industry, agriculture and tourism), urban development and demographic changes. The design of measures in RBMP should therefore be coordinated and spatial planning by Member States should take account of climate change, water scarcity and flood risks. Such an integrated approach to water management becomes even more important as our climate is changing. An **institutionalised process of cooperation** on climate adaptation and water management is needed, as is staff training through capacity-building programmes.

NATURE-BASED SOLUTIONS FOR RESILIENCE & CLIMATE ADAPTATION

49. It is recommended to avoid structural changes to water bodies as much as possible, as the best resilience to face climate change is often provided by **preserving or restoring the natural state of ecosystems.** Nature-based solutions (NBS) for making water ecosystems more resilient to climate change offer multifaceted benefits including improved water retention, enhanced biodiversity, and climate change mitigation through carbon sequestration. They promote resilience to climate change impacts, including flooding and droughts, while fostering sustainable communities. NBS also play a crucial role in improving water quality and enhancing hydromorphology. They mitigate the vulnerability of water systems to droughts, providing alternative water access through natural reservoirs. NBS implementation spans across various scales, from large-scale river restorations to localised urban infiltration projects, effectively addressing different flood risks and water management needs.

50. Economic assessments of NBS for flood and drought management have demonstrated **favourable benefit-cost ratios** and highlighted the multiple **co-benefits**. Challenges to

implement NBS remain, including insufficient demonstration of their multiple benefits compared to grey alternatives, limited understanding of their effectiveness against high-risk extreme floods, and scarcity of land adjacent to water bodies for implementation. Additionally, there is a limited mobilisation of finances and inadequate consideration of climate change impacts on NBS functionality and resilience.

CROSS-BORDER/TRANSBOUNDARY ASPECTS OF CLIMATE ADAPTATION

51. Transboundary cooperation for climate adaptation involves collaborative efforts among neighbouring countries to address common challenges and opportunities. This collaboration requires navigating conflicting interests and needs while promoting the sharing of data, resources, and expertise. By working together, countries can achieve greater efficiency in adaptation efforts, avoid unintended consequences of unilateral actions (maladaptation), and promote sustainable development and regional integration.

52. Establishing robust **data exchange** mechanisms is essential for enhancing transboundary cooperation in climate resilient water management. By standardising data collection, sharing processes, and information exchange protocols, countries can improve coordination and decision-making on water management issues. International agreements and collaborative platforms facilitate the exchange of crucial information among riparian countries, supporting integrated approaches to water resource management and climate adaptation.

53. Effective management of international water bodies requires **institutional frameworks** and principles of integrated water resource management. Basin-wide agreements provide a foundation for transboundary cooperation, guiding collaborative efforts and promoting harmonisation of methodologies and strategies. By adopting shared approaches to climate adaptation, countries can address common challenges, promote sustainable development, and build resilience to climate change impacts.

54. Implementing adaptation plans necessitates close coordination with other relevant policies and stakeholders. By aligning adaptation efforts with existing policies and engaging stakeholders across sectors, countries can maximise synergies, secure funding, and enhance the effectiveness of adaptation measures. Prioritising actions that benefit the entire basin, sharing costs and benefits, and leveraging local knowledge are essential strategies for successful adaptation while minimising conflicts and vulnerabilities within the basin.

HOW TO DO A CLIMATE CHECK OF WFD MEASURES

55. A climate check of measures involves potentially two main steps: **screening the Programme of Measures** (PoM) level and detailed **proofing for individual projects**. Screening assesses climate robustness and a contribution to mitigation and adaptation, ensuring measures align with objectives and climate goals. Detailed proofing integrates

climate change aspects into project development, focusing on mitigation and adaptation. It involves an early assessment of GHG emissions and climate resilience, ensuring projects are compatible with climate targets and are resilient to future impacts.

56. The screening phase evaluates measures relevance, effectiveness, flexibility, and side effects under changing climatic conditions. It considers adjustments needed, safety margins, and coherence with climate adaptation strategies. This ensures measures remain effective and adaptable, contributing to climate resilience while avoiding maladaptation. Screening identifies key areas for further analysis and adaptation planning, guiding decision-making in water management.

57. Detailed proofing integrates climate mitigation and adaptation aspects into project development, aligning with EU climate objectives. It involves assessing GHG emissions and climate resilience, ensuring projects are compatible with climate targets and resilient to future impacts. The process includes early assessment of GHG emissions, considering energy efficiency and mitigation options to reduce the carbon footprint. It also evaluates climate vulnerabilities and risks, identifying and implementing suitable adaptation measures.

1 INTRODUCTION

EU waters are affected by various human activities, e.g. land use and land use change, water abstraction, construction of infrastructure, fisheries, the introduction of invasive alien species and pollution with nutrients and hazardous substances. Those pressures are aggravated by the growing impacts of climate change, such as faster or prolonged snow melting periods, shortened groundwater formation periods, warmer soils with increased biological activity that affects water quality and causes an increase in weather and climate extremes like cloudbursts and heat waves, as well as more frequent and more severe periods of extreme droughts and floods[5]. Also, stronger evaporation due to the rise of the average water and air temperature, seasonal changes in precipitation and sea level have an impact on the biological, ecological, and chemical status of European water bodies. The damage to the water system generates very high economic losses. For example, a recent study estimates the economic drought-related losses in the EU to be 9,4 billion euros each year. In a 3°C global warming scenario, these costs would rise to 45 billion Euro/year by 2100 (Feyen et al., 2020).

Hence, under current and future climate change conditions, it is even more necessary to achieve sustainable management of European freshwaters, transitional and coastal waters, ensuring good water quality and access to sufficient quantity for sustainable, balanced and equitable water use (Article 1, WFD). It is also necessary to adapt to the unavoidable negative consequences of climate change that will occur even if we reach climate neutrality.

What is the purpose of this guidance?

This guidance document i) updates information on climate change impacts on the water cycle and ii) provides tools to help water managers align River Basin Management (RBM) planning under the Water Framework Directive (WFD) and the Floods Directive (FD) to climate adaptation planning.

The WFD (EU, 2000) was adopted 8 years after the UN Framework Convention on Combat Climate Change (UNFCCC, 1992). Thus, the need to reduce greenhouse gases (GHG) as well as the impacts of climate change were already well known. Article 1 of the WFD indicates that one of its purposes is to establish a framework to mitigate the effects of droughts and floods. However, there is no explicit provision in the Directive on how to take climate change into account in RBM. One important step to complement the WFD was taken in 2007 with the FD.

Two years later, in 2009, Guidance Document No 24, 'RBM in a Changing Climate' was published as part of the Common Implementation Strategy (CIS) of both the WFD and FD.

[5] See the Glossary for the definitions.

That guidance was a first step in developing a methodology to support Member States (MSs) in including climate change considerations in their water management in the programmes of measures (PoM) of the RBM cycles and in the flood risk management cycles.

In 2013, the European adaptation strategy encouraged EU MSs to adopt comprehensive climate adaptation strategies. Between 2013 and 2018, the number of MSs with adaptation strategies sharply increased from 15 to 25. By 2020, all MSs had prepared such strategies. However, these varied greatly in scope, delivery, and implementation methods.

In 2021, a new EU strategy for climate adaptation was adopted to respond to the meanwhile unavoidable impacts of climate change which require increased adaptation efforts. The strategy, part of the European Green Deal, aims to accelerate efforts to protect nature, people and livelihoods against the impacts of climate change. In July 2021, the European Climate Law entered into force. The regulation provides for national adaptation strategies and plans alongside climate adaptation planning at the Union level[6] and formulates expectations regarding the quality of national adaptation policies and their outcome. In accordance with Article 7 of the Paris Agreement, the Climate Law also established a "duty to adapt" to ensure continuous progress in enhancing the adaptive capacity, strengthening resilience and reducing vulnerability to climate change.

National adaptation strategies of MSs shall take into account particular vulnerabilities of relevant sectors including the "water/soil and food nexus". They shall promote Nature-based Solutions (NBSs) and ecosystem-based adaptation. MSs shall regularly update national climate adaptation strategies and include the updated information in climate adaptation reports. The Climate Law also tasks the Commission with regularly assessing the consistency of relevant national measures with their national adaptation plans and issuing recommendations if such measures are seen insufficient to reduce climate change vulnerability.

In 2021, the Commission adopted new **technical guidance for the "climate-proofing" of infrastructure projects** for the period 2021-2027. This guidance[7] are in line with Article 5 (5) of the Climate Law, which stipulates that the Commission shall adopt guidelines setting out common principles and practices for the identification, classification and prudent management of physical climate risks when planning, developing, executing and monitoring projects and programmes for projects.

In addition, the **C**ommission has published in 2023 **guidelines on Member States' adaptation strategies and plans**[8], based on a review of the 2013 guidelines on developing adaptation strategies. The new guidelines give an overview of features that are essential for (re)crafting

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[6] Article 5 (2) Regulation (EU) 2021/1119 *"The Commission shall adopt a Union strategy on adaptation to climate change in line with the Paris Agreement and shall regularly review it in the context of the review provided for in point (b) of Article 6(2) of this Regulation".*

[7] Commission Notice *Technical guidance on the climate proofing of infrastructure in the period 2021-2027* (2021/C 373/01), available for download here.

[8] 2023/C 264/01

strong adaptation policies and plans, such as a proper legal framework, regularly updated adaptation strategies and plans with clear adaptation policy priorities.

There is a virtuous feedback loop between RBM planning and climate adaptation planning. RBM and flood risk management drive PoMs to improve the water cycle but can also deliver robust data for national and regional climate adaptation planning. Conversely, the objectives of national and regional climate adaptation plans should be carefully considered in river basin and Flood Risk Management Plans (FRMP) to account for climate change.

This feedback loop can, however, be hampered by a mismatch of planning cycles and by lacking coordination between public authorities.

For historical reasons, the planning cycles under the EU Climate Law, the WFD and FD are not aligned. From 30 September 2023, the reporting cycle is every five years under the EU Climate Law. Every five years, the Commission shall assess (a) the collective progress made by all MSs towards achieving the climate-neutrality objective to reduce climate emissions to net zero by 2050; and (b) the collective progress made by all MSs on climate adaptation. Under the WFD and FD, the implementation cycles are six years.

Moreover, MSs may assign competencies for water management and climate adaptation planning to different public bodies. As with other areas of public policy, this can lead to coordination issues and friction within MSs. Moreover, the need to align water and flood risk management in a transboundary manner can be hampered by diverging views among MSs on climate adaptation needs. For example, neighbouring countries may have common groundwater bodies as well as freshwater, estuarine and coastal surface waterbodies. Water managers in such regions should ideally coordinate water abstraction and water allocation permits in transboundary regions. This can be difficult in the absence of coordinated MSs for climate adaptation needs.

To achieve the positive feedback loop between climate adaptation and RBM, this guidance builds on the six-step approach of the Regional Adaptation Support Tool (RAST) to develop and implement adaption strategies (Climate ADAPT, 2023a).

Who is this Guidance intended for?

This Guidance largely addresses practitioners within competent authorities responsible for the management of surface and groundwater as well as coastal and marine areas. Yet, it is also meant to assist authorities in dealing with climate change adaptation in a broader context. Though, equally important, it is meant to inform and guide all stakeholders playing a role in water management at national, regional, and local levels.

What is included in this Guidance?

This guidance provides the most recent scientific findings on interactions between climate change and water based on models, projections, and scenarios. In addition, it builds on concrete initiatives and developments included in the European Climate Adaptation Platform Climate-

ADAPT[9]. It provides a methodology to prepare, implement and monitor actions for adapting water management to ongoing and future climate change impacts. These Guidelines are structured according to the following chapters:

Chapter 1	Introduces the guidance document
Chapter 2	Gives an overview of current climate modelling and scenarios. It aims to describe the status quo and raise awareness about the urgency of the climate crisis and its main effect on Europe.
Chapter 3	Creates an overview of the WFD and the FD, the most important related documents and other policies with a water-related context.
Chapter 4	Provides an overview of more resilient water management strategies in line with the climate Adaptation Support Tool and the 6-step climate adaptation cycle
Chapter 5	Gives an overview of guiding principles related to climate change and the RBM under the WFD.
Chapter 6	Follows the three steps (PFRA, FHRM and FRMP) of the FD´s risk management cycle. It proposes strategies to integrate climate change. Furthermore, it discusses adaptation measures related to the FD.
Chapter 7	Discusses the ability of drought management, climate adaption, the role of RBMP, DMP or other strategies adopted by MSs as supporting tools to address droughts and water scarcity.
Chapter 8	Focuses on Nature-based Solutions and how the restoration and enhancement of ecosystem services can protect society against the negative impacts of climate change in a cost-efficient way.
Chapter 9	Summarises the transboundary aspects of adaptation and provides a guideline to enhance transboundary cooperation in line with a joint vision for climate adaptation needs.
Chapter 10	Discusses how to do a climate check on measures (adaptation and mitigation) based on a screening phase and a detailed proofing of infrastructure projects.

2 CLIMATE MODELLING, PROJECTIONS AND SCENARIOS

2.1 Observed climate change at the global level

The latest IPCC assessment confirms that the rapid warming of the atmosphere, land, oceans, and cryosphere results from human-driven increases in greenhouse gases (GHG). Carbon dioxide concentrations in the atmosphere continue to rise, already resulting in a 1.09 °C global mean temperature increase compared to pre-industrial levels (IPCC, 2022). A mean temperature increase of 1.5°C and 2 °C is likely to occur this century without significant emission reductions. This was highlighted by the record year 2023, in which the global average temperature was around 1.45 °C above pre-industrial levels as well as above 1.5 °C in the last 12 months since February 2023 (EEA, 2024). Irreversible changes are already happening, particularly in oceans, ice sheets, and sea levels (IPCC, 2022). Keeping the temperature increase to 1.5 ° C would require a cut in global GHG emissions of 43% by 2030 compared to

[9] The MSs are at different stages of preparing, developing, and implementing NASs and NAPs. Climate-ADAPT prepares an overview of each country's reporting along with links to the public submission of the documents. The reporting follows a consistent structure starting with a summary; assessments of e.g. climate modelling, projections, scenarios, methods and tools; legal and policy frameworks; strategies plans and goals; monitoring and evaluation methodology; good practice, cooperation and synergies; and contacts.

2010. Instead, emissions are expected to continue rising to about 10% above 2010 levels. Current policies point to a 2.8 ° C temperature rise by the end of the century, and implementation of all COP26 pledges would only reduce this to a 2.4-2.6 ° C temperature rise (UNEP, 2022).

The temperature rise has already led to or will most likely lead to the following impacts:

i. More frequent and intense weather extremes, including heatwaves, heavy precipitation, droughts, and cyclones, are observed globally. There is also a trend to hotter extremes and reduced cold extremes since the 1950s.
ii. Water-related risks and hazards will grow, with higher global warming levels posing greater threats. Water management challenges will intensify, especially in resource-constrained regions, due to the magnitude and speed of future climate change.
iii. Climate change-triggered extreme events are pushing natural and human systems beyond their adaptive capacities, causing widespread adverse impacts and damages. The figure below gives an overview of in which areas people will be exposed to deadly heat and humidity conditions depending on the different global temperature developments (IPCC, 2022).

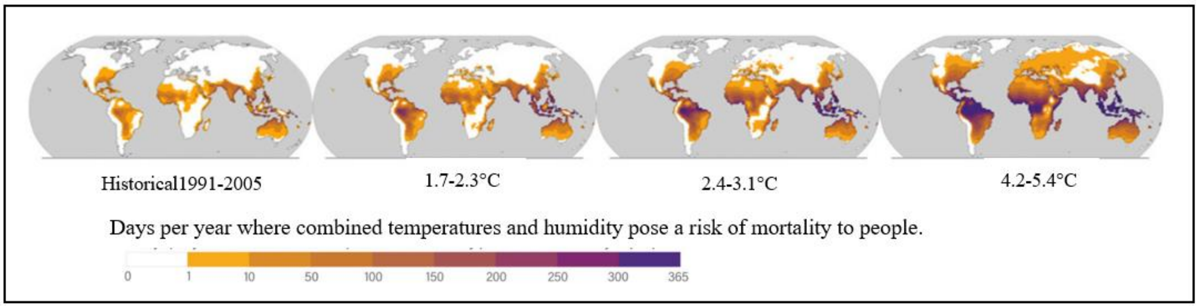

Figure 1: Projected development of areas where people will be exposed to possible deadly heat and humidity conditions (IPCC, 2022).

2.2 Climate Change observations and projections for the EU and their impacts

Europe is the fastest-warming continent in the world (EEA, 2024), rising already by 1.94 to 2.01 °C on average from 2010-2020 compared to pre-industrial levels. The warmest years have occurred in the past decade, with winters getting milder and summers hotter and recurrent severe extremes such as drought, heatwaves, and floods (IPCC, 2022).

Extremely hot weather events are set to intensify across Europe under all emissions scenarios. Critical warming thresholds, especially beyond 2 °C, could lead to severe impacts on ecosystems and humans, particularly in southern regions, due to the extreme heat, water scarcity, drought, and forest fires (IPCC, 2022). Europe will experience more intense and frequent weather and climate extremes, including droughts and flash floods. While complex extremes and disasters with cascading effects will emerge.

The ongoing temperature increase in Europe is projected to continue throughout the 21st century under all scenarios. Surface temperature is projected to increase by 1.3-3.4 °C under SSP1-2.6[10] and by 4.1-8.5 °C under SSP5-8.5. Climate change projections reveal regional differences in Europe, e.g., as the highest temperature increases are expected in north-eastern Europe and Scandinavia during winter and in southern Europe in summer (EEA, 2019).

[10] SSP: Shared Economic Pathway

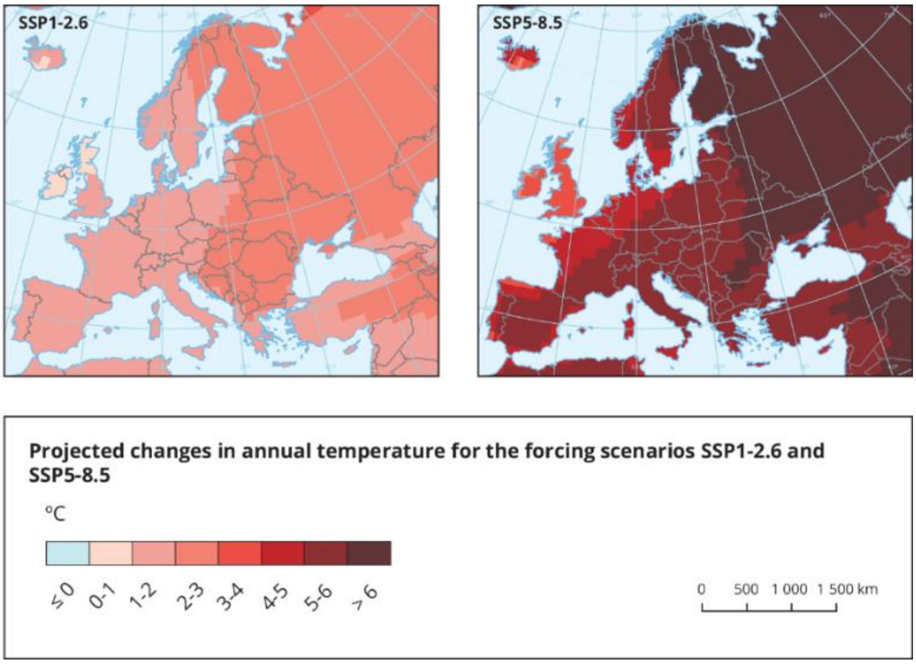

Figure 2: Projected changes in near-surface air temperature under different SSP emission scenarios (SSP1-2.6 and SSP5-8.5) in Europe (°C) when comparing the reference periods 1981-2010 and 2081-2100. Source: EEA website using data from CMIP6. This data was used in the IPCC AR6 report.

The main impacts on the EU water resources are summarised in Table 1 to provide an overview of the expected water-related changes in different parts of Europe, followed by a more detailed description.

Table 1: Expected change of water-related hazards in Europe (IPCC, 2022; EEA, 2021)..

Hazard	*Indicator*	*Northern Europe*	*Central Europe*	*Southern Europe*
Precipitation	Total precipitation	Annual ↗	Annual ↗↘	Annual ↘
		Summer ↗↘	Summer ↘	Summer ↘
	Maximum consecutive 5-day precipitation	↗	↗	↗
	Extreme precipitation total	↗	↗	↗
	Frequency of extreme precipitation	↗	↗	↗
River Floods	River flood index using runoff	↗↘	↗	↗↘
Aridity	Aridity actual	↗	↗↘	↗
	Consecutive dry days	→	↗	↗
Drought	Frequency of meteorological droughts	↗	↗	↗
	The magnitude of meteorological droughts	↗	↗	↗
	Frequency of soil moisture droughts	↗	↗	↗

Legend:

↗	Increase throughout most of a region

↘	Decrease throughout most of a region
⤨	Increase as well as decrease in a region
→	No significant changes from the current situation

Changes in annual precipitation and water flow

i. In the recent past, annual precipitation has not shown a clear significant trend in Europe, although seasonal tendencies have been detected. In the future, summer precipitation is expected to decrease in most of Europe (except its Northernmost part). Winter precipitation is projected to increase in Northern Europe and decrease in the Mediterranean region. Changes in precipitation type, particularly snowfall, will also have implications for river flow (IPCC, 2022). European countries are also experiencing an increased share of their annual precipitation falling during heavy rain events (EEA, 2021).

Example 1: Glacier melt in the Alps.

The flow of the glacier-fed rivers Rhine, Rhone, Danube and Po is still showing some continuity related to glacier melting. This part of their base flow is relatively growing during heat waves. Before 2100 and in the eastern parts of the Alps already before 2050, the glaciers will have vanished and so will the base flow related to this. This means a substantial change for the glacier-fed rivers towards a rainfed river plus a substantial reduction of their flow (BRLi, 2023).

Floods

ii. Various indices of heavy precipitation point to a future increase in such events in Europe, especially in its northern part which has been already experiencing an increasing trend (EEA, 2021).

iii. Fifty-year river flood levels are projected to increase across most of Europe, especially in central and central-eastern Europe. Expected changes in southern Europe are more varied and uncertain. Floods related to intense precipitation and excessive soil moisture are expected to increase (IPCC, 2022).

Aridity

iv. Aridity is currently highest in the southernmost regions of Europe, and it generally tapers off towards the north. Broadly, Europe is likely to experience more aridity in the future, especially in areas just north of the current ‘aridity hotspots’ (the northern part of the Iberian Peninsula, Turkey and the Balkans) (EEA, 2021).

Droughts

v. Due to enhanced evaporation, a drying trend in Europe as a whole has accelerated during recent decades, which is strongest in southern and central-eastern Europe. Hydrological droughts have increased in southern Europe and in spring and summer for western and northern Europe (EEA, 2024).

vi. Future changes in droughts vary depending on the season. In winter, the frequency of drought is expected to increase in the Mediterranean region, while decreases are projected in most of the other European regions. In all the other seasons, and especially in summer, the frequency and severity of drought events are expected to increase (IPCC, 2022).

vii. Soil moisture content has significantly dropped in southern Europe and increased in parts of northern Europe; this trend is projected to continue with a decline in the top-soil moisture content that will affect Europe (IPCC, 2022).

viii. The duration of dry spells has been largely stable throughout Europe so far. For the future, large increases are projected for southern Europe, smaller increases for central Europe and no significant changes for northern Europe (EEA, 2021).

Sea level rise and extreme sea level

ix. Globally, mean sea levels - the height of seawater relative to land - have been rising for more than a century, with accelerating rates in recent decades due to warming oceans and melting glaciers and ice sheets (EEA, 2021).

x. The relative sea level of Europe’s seas will continue to rise throughout this century under all emissions scenarios. Under a high-emissions scenario, the rise is expected to be greater than 0.60 m along most of the European coastline. The only exception is the Northern Baltic Sea, where current coastal floods are projected to become rarer because of continued land uplift following the last ice age (EEA, 2021).

Water temperature

xi. River temperatures face increases in median values between 1.3 °C and 3.8 °C (van Wesenbeeck et al., 2021)). Lake surface temperatures are warming at a rate of 0.33 °C per decade, which is faster than the global rate of 0.23 °C per decade (EEA, 2024). Increasing water temperature leads to higher evaporation rates, resulting in reduced water volumes in lakes worldwide (Zhao, Li, Zhou, & Gao, 2022). Global annual mean lake evaporation rates are projected to rise by 16% by 2100, impacting lake levels and surface water extent (Woolway, et al., 2020). The sea surface temperature has increased since 1980 by 0.5°C globally and around 1.1°C for Europe and have reached unprecedented levels in 2023 (EEA, 2024).

2.3 Impact on water body status

The key objective of the WFD is to achieve both good chemical and ecological status, the latter an expression of the quality of the structure and functioning of aquatic ecosystems that includes biological, physiochemical and hydromorphological parameters. The changes caused by climate change, as described in the previous chapter, have an impact on the ecosystems in different ways.

Changes in annual precipitation and water flow

i. The hydro morphological character of waterbodies will be altered by changing precipitation patterns including less snowfall and retention will reshape the annual hydrograph which will degrade biological communities through scouring or desiccation, reducing biodiversity and lowering ecological status (IPCC, 2022). Alteration of river flow, also through engineering responses, will have serious consequences on processes such as sediment provision and transport, altering waterbody morphology and physical habitats. This will lead to changes in species composition successively reducing resilience with climate change progression (O'Briain, 2019).

Floods

ii. Flooding or more frequent summer storms can deliver heavy nutrient loads from agricultural land to lakes and rivers during short time intervals and can also cause more storm overflows in urban wastewater distribution systems, estimated to increase by 37% in volume for a high emissions scenario (Abdellatif, et al., 2015). Also, slope mass movements”, caused by extreme weather events might increase (Stoffel, Tiranti, & Huggel, 2014).

Aridity and droughts

iii. Increased evaporation and reduced flow lead to less dilution of nutrients, especially in rivers receiving urban wastewater and diffuse pollution from agricultural areas. Concentrations of phosphorus and ammonium have been predicted to double with climate change in Mediterranean rivers during low-flow months (Dorado-Guerra, et al., 2023). Droughts also favour salt-water intrusions in coastal areas with irrigation linked to increasing salinity in river basins (Thorslund, et al., 2021).

Sea level rise and extreme sea level

iv. An unavoidable drawback of the strong rise in sea levels and the consequent need for adaptation is that in about 25% of the coastline of the EU, the sea would be disconnected from the hinterland by natural or physical barriers (Feyen et al., 2020).

v. The spatially averaged median value of sea level rise driving potential shoreline retreat of sandy beaches in Europe by 2100, relative to the baseline year 2010, is projected to be about 97 m under a high emission scenario and 54 m under a medium emission scenario. These hotspots include regions along the Italian Adriatic coast, the French Atlantic coast, the east part of the Baltic Sea and around the North Sea (Athanasiou, et al., 2020).

vi. With some limitations to the data, historical once-in-a-hundred-years coastal floods are projected to occur several times a year on the Mediterranean Sea and the Black Sea coasts, at least once a year along most other European coasts under a high-emissions scenario and at least once a decade along the remaining European coasts even under lower emissions scenarios (EEA, 2021).

vii. The rising sea level leads to the salination of freshwater sources that many coastal areas use for their drinking water (IPCC, 2019)

viii. Tidal marshes depend on a sufficient sediment load to cope with sea level rise and to allow accretion and a tidal range, but many are likely to become sub-tidal by the end of the century. Migration of zones landward is possible if this is not blocked by natural or anthropogenic barriers (Short, et al., 2016).

Water temperature

ix. Increasing water temperature can have a direct physiological response in biota increasing respiration, while the increasingly frequent pattern of heatwaves followed by colder low-pressure systems can cause metabolic disruption, potentially inducing fish kills (Jeppesen, et al., 2021).

x. Warmer temperatures can lead to altered stratification regimes in lakes and transitional and coastal waters altering nutrient cycling and isolating lower layers from the atmosphere reducing oxygen (Rogora, et al., 2018). Seasonal mismatch is already occurring with alteration to the traditional start, length and end of seasons altering species phenology resulting in a mismatch between prey and predators, with implications across ecosystems (IPCC, 2022).

xi. Geochemical parameters and processes will also be increasingly affected by warmer temperatures and an increased soil moisture deficit has been predicted to lead to an increase in the mineralisation of nitrogen by over 30% following rewetting (McAleer, et al., 2022) and together with changes in land use and hydrology has already been blamed for increasing Nitrogen export to the Baltic (Räike, Taskinen, & Knuuttila, 2020).

2.4 Socio-economic impacts on water-dependent sectors and society

Water-related activities in Europe use around 243 billion m³ of water annually. Within the EU agriculture accounts for the largest share of water use with around 40% of the total water used per year, followed by 28% for energy production, 18% for mining and manufacturing and 12 % for household use. These values vary significantly across Member States (EEA, 2018). More than half of the water used (over 140,000 billion cubic meters) is returned to the environment but it then often contains impurities or pollutants, including hazardous chemicals. Climate change and the more frequent occurrence of hazards will have an impact on the economy and its sectors.

Economic losses

i. Between 1980 and 2022, climate-related extremes reached estimated losses of about 650 billion Euros in the EU. Hydrological hazards (floods) account for almost 43% and meteorological hazards (storms, including lightning and hail, together with mass movements) for around 29% of the total. As for the climatological hazards, heat waves caused around 20% of the total losses while the remaining approx. 8% is associated with droughts, forest fires and cold waves together (EEA, 2023b).

ii. The European Insurance and Occupational Pensions Authority's Pilot dashboard on insurance protection provides a comprehensive view of the protection gap, revealing that merely 35% of the overall losses resulting from extreme weather and climate-related events in Europe are covered by insurance (EIOPA, 2019).

iii. **Droughts**: Without climate mitigation and adaptation actions, total drought losses for the EU and the UK would increase to at least 45 billion Euros each year in a 3 °C warming scenario compared to about 9 billion Euros/year at present (Feyen et al., 2020)). The number of people in Europe living in areas with water resources under stress will increase to 65 million in a 3 °C warming scenario and the people living under severe water stress, now around 3.3 million, would become fourfold in a 3 °C warming scenario. In some parts of southern Europe, practically all available water will be used in the summer months, and the majority of people and economic activities in these regions will face water scarcity (Feyen et al., 2020)).

iv. **Floods**: If no mitigation and adaptation measures are taken, economic losses will grow to nearly 50 billion Euros a year with 3°C global warming by 2100 and 482 million Europeans due to river flooding, compared to 7.8 billion Euros/year and 172 billion Euros/year at present (Feyen et al., 2020).

v. **Coastal floods**: Annual damage from coastal flooding is projected to increase from 1.4 billion Euros/year to 240 billion Euros/year by 2100 with no mitigation and adaptation measures taken and can expose up to 2.2 million people each year (Feyen et al., 2020).

Agriculture

vi. Rising temperatures, altered precipitation patterns, and increased climate extremes will result in increased drought-driven yield losses and flood-related risks to agricultural production, with potential implications for food safety and security (IPCC, 2022).

Industry, energy and waterborne transport

vii. The future is likely to witness a substantial rise in freshwater demand for energy and industrial sectors globally, leading to increased competition for water resources across sectors. Although climate change also poses challenges to water-intensive industries like mining, quantifying these risks remains difficult due to limited research and data (IPCC, 2022).

viii. Recent modelling suggests that the European energy sector could be subject to stress in extreme drought scenarios. The European energy system is a major water user except for wind and solar power, as water is required for hydropower generation, but also for plant cooling in thermoelectric production and bulk transport (of coal) on major rivers.

ix. Climate change represents a significant safety and business continuity risk to waterborne transport operations and infrastructure – and hence to local, national and regional economies. Seaports are exposed to sea level rise and extreme weather, including storms, changes in wind speed or direction and significant wave heights (IPCC, 2022).

x. Inland waterways are particularly susceptible to changes in seasonal precipitation (both rain and snow) as well as glacier melt because these phenomena dictate the frequency and severity of extreme high and low flow conditions (PIANC, 2020).

xi. In terms of economic losses, the interruption in the logistics chains caused by the low-water event in 2018, caused considerable economic losses which, for example, resulted in a decrease in German industrial production by almost 5 billion Euros (CCNR, 2021).

Public water supply and tourism

xii. Recent modelling suggests that the demand for public water supply in Europe may increase by up to 10% with strong regional variations. The highest extra abstractions will occur in the most water-rich countries (Scandinavia) which quite likely will have enough water to cope with such extra abstractions. Slightly elevated values (up to 5% extra abstractions) are also expected in dry southern regions where such extra demands may, however, come close to the maximum supply of freshwater resources, meaning that there may be less room for extra abstractions.

xiii. In some MSs, rivers and coasts support water-based tourism and recreation activities that significantly contribute to the socio-economic (employment) and/or health and well-being status. Changes in the frequency and severity of high and low flow conditions, sea level rise and sediment dynamics will affect these activities. Changes in physio-chemical conditions, like environmental quality deterioration due to nutrient enrichment, or water temperature increases will lead to changes in vegetation growth rates, species' range shifts, and invasions of alien species.

3 WATER AND CLIMATE CHANGE – EU POLICY FRAMEWORK

The EU **Water Framework Directive** and the **Floods Directive**

i. Water Framework Directive (2000): The WFD established a legal framework to protect and restore the water environment across Europe by 2015 to ensure the long-term sustainable use of water. MSs were allowed to prolong the implementation time if justified, but the WFD objectives should be achieved by 2027 at the latest.
   a. 6th WFD and FD Implementation Report (2021): While a large majority of groundwater bodies have achieved a good status, less than half of surface water bodies are at a good status, even though the deadline for achieving this was 2015, except for duly justified cases.
   b. Fitness check (2019): The report has concluded that the WFD has been largely successful in setting up a governance framework for integrated water management for more than 110,000 surface water bodies in the EU, slowing down the deterioration of water status and reducing chemical pollution. Still, the fitness check reported that additional efforts are needed in many MSs.

ii. Floods Directive (2007): The FD established a legal framework for the assessment and management of flood risks across MSs, aiming to reduce the adverse consequences of floods to human health, the environment, cultural heritage, and economic activities by developing PFRA, FHRM and a FRMP.

EU **Water Scarcity** and **Drought Policy**

i. Addressing the challenge of water scarcity and droughts in the European Union (2007): The report identified key policy options for addressing water quantity management, including options related to 'putting the right price tag on water', 'allocating water more efficiently' and 'fostering water efficient technologies and practices'.

ii. Blueprint for Safeguarding European Waters (2012): The report notes that limited progress has been achieved in implementing the policy instruments identified in 2007. As a follow-up and to enforce good water management, several Guidance documents were adopted under the CIS (e.g. on ecological flows and water balances).

iii. European Green Deal (2019) and related policies:
   a. Circular Economy Action Plan (2020): The plan emphasises acceleration for water reuse and efficiency, including in industrial processes.
   b. Regulation on minimum requirements for water reuse for agricultural irrigation (2020).
   c. Guidelines to support the application of Regulation 2020/741 on minimum requirements for water (2022): The guidelines should support the application of the regulation on the general and administrative obligations, its scope of application, and

its technical aspects, such as risk management and validation monitoring, as well as several practical examples.

iv. Biodiversity Strategy for 2030 (2020): It sets out a commitment to legally protect a minimum of 30% of the land, including inland waters, and 30% of the sea in the EU, of which at least one third should be under strict protection. Part of the objective is the restoration of at least 25,000 km of free-flowing rivers, including the removal of primarily obsolete barriers and the restoration of floodplains and wetlands.

   d. Nature Restoration Law (2023): Set binding targets to restore damaged ecosystems and bring nature back across Europe. Altogether, these restoration measures should cover at least 20% of the EU’s land and sea area by 2030, and all ecosystems in need of restoration by 2050.

   e. The Proposal for a Forest Monitoring Directive/Regulation (to be adopted soon) and the Forest Strategy 2030 (2021): The strategy sets a vision and concrete actions to improve the quantity and quality of EU forests and strengthen their protection, restoration and resilience.

   f. The Proposal for a Soil Monitoring and Resilience Directive (2023) and Soil Strategy 2030 **(**2021): Provide a framework and concrete measures to protect and restore soils and ensure sustainable use. To achieve healthy soils and aquatic ecosystems it is essential to coordinate water and soil policies through better soil and water management, across borders, and reduce the impact of floods and droughts on people and economy.

v. EU Strategy on Adaptation to Climate Change (2021): The strategy aims to realise the vision that in 2050, the EU will be a climate-resilient society, fully adapted to the unavoidable impacts of climate change. To achieve reinforced adaptive capacity and minimised vulnerability to climate impacts, adaptation will be made smarter, more systemic, swifter, and by stepping up international action. The Commission will help to close knowledge gaps on climate impacts and resilience, including on ecosystems, both on land and in the oceans. It promotes mainstreaming adaptation into various policy areas and will support improving adaptation strategies and plans, as well as promote NBS for adaptation. The Commission also committed to help ensure a climate-resilient, sustainable use and management of water across sectors and borders by improving the coordination of thematic plans and other mechanisms, such as water resource allocation and water permits. It will also help reduce water use by encouraging water efficiency and saving, by promoting the wider use of DMP as well as sustainable soil management and land-use. This strategy coincided with the implementation of the European Climate Law which implements the Paris Agreement's objectives[11].

vi. European Climate Law (2021): It sets into legislation the goal for Europe’s economy and society to become climate neutral by 2050. It also sets the intermediate target of reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels. It also includes strong provisions on adaptation to climate change, such as the requirement that relevant EU institutions and the MSs ‘ensure continuous progress in enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change’. MSs shall in their national adaptation strategies and plans, among others, consider the particular vulnerability of the relevant sectors, inter alia, of water and food systems, and promote nature-based solutions.

vii. Communication on Managing Climate Risks (2024): It responds to the first ever European Climate Risk Assessment (2024). The communication sets out how the EU and its Member

[11] The Paris Agreement is the legally binding international treaty on climate change adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. The Paris Agreement entered into force on 4 November 2016 and is binding for the Member States of the European Union. Since 2019, it forms the basis for implementation meetings of the Conference of the Parties (COP) for the United Nations Framework Convention on Climate Change (UNFCCC).

States can better anticipate, understand, and address growing climate-related risks. It sets out EU actions in the main impact clusters: natural ecosystems, water, health, food, infrastructure and the built environment, and the economy.

Other relevant EU policies and legislation

i. Strategic Foresight Report (2023): An annual report published by the Commission, giving insights into trends, risks, emerging issues and their potential implications and opportunities to support strategic planning, policymaking, and preparedness.
ii. EU regulation on land, land use change and forestry (2023)**:** The regulation addresses the land use sector's impact on the EU's climate goals up to 2030. A novel approach separates the land-based net carbon removal target, requiring a reduction of 310 million tonnes of CO_2 equivalent by 2030.
iii. Renewable Energy Directive (RED III) (2009): It establishes a common framework to promote energy stemming from renewable sources in the EU and sets a binding target of 42,5 % for the overall share of energy consumption to come from renewable sources in the EU's gross final consumption in 2030. The proposal for the amendment of the Directive proposes that, in the permit-granting process, the planning, construction and operation of plants for renewable energy production, their connection to the grid and the related grid itself and storage assets are presumed as being in the overriding public interest and serving public health and safety when balancing legal interests in the individual cases for the purposes of …, Article 4(7) of Directive 2000/60/EC…'
iv. REPowerEU (2022): With this plan, the EU wants to fight climate change and end its dependence on Russian fossil fuels. In order to tackle slow and complex permitting for major renewable projects, using energy from renewable sources should be considered as an overriding public interest. Dedicated 'go-to' areas for renewables should be put in place by MSs with shortened and simplified permitting processes in areas with lower environmental risks.
v. Drinking Water Directive **(**2021): This Directive is related to the WFD and includes a risk-based approach throughout the entire drinking water supply chain. This requires risk assessment and risk management of catchment areas for abstraction points of drinking water sources and for the supply system.
vi. Urban Waste Water Treatment Directive (2022): The revision of the directive aims to modernise standards, reduce pollution, improve water quality, and enhance access to sanitation across the EU. By enforcing stricter regulations, monitoring pathogens, and addressing micropollutants, the EU seeks to achieve significant environmental and public health benefits while promoting a more sustainable and circular wastewater management sector.
vii. Common Agricultural Policy, CAP (2021): The CAP aims to support farmers and improve agricultural productivity, ensuring a sustainable and stable supply of affordable high-quality food, supporting EU farmers in making a reasonable living, helping to tackle climate change and the sustainable management of natural resources, to maintain rural areas and landscapes across the EU and keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sectors.
viii. Marine Strategy Framework Directive (2008): The Directive was put in place to protect marine ecosystems and biodiversity upon which our health and marine-related economic and social activities depend and further support EU countries achieve good environmental status.
    a. Action Plan 'Protecting and restoring marine ecosystems for sustainable and resilient fisheries' (2023): The action plan aims to use synergies between the EU fisheries and environmental law. In doing so, it aims at improving fisheries' sustainability and better protecting marine ecosystems and habitats, including supporting them in the process of adaptation to climate change.

ix. Trans-European Transport Network (2013): The policy addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals.

x. NAIADES III (2021): The core objectives of this 35-point action plan are to boost the role of inland waterway transport, shift more cargo to Europe´s rivers and canals and facilitate the transition to zero-emission barges by 2050.

xi. EU Taxonomy Climate and Environment Delegated Acts (2022 and 2023): The acts aim to support sustainable investments by clarifying which economic activities most contribute to meeting the EU's climate and environmental objectives.

xii. Environmental Crime Directive (2008): The directive aims at supplementing existing administrative sanction systems with criminal law penalties to strengthen compliance with the laws for the protection of the environment. In 2021, the Commission revised the directive and adopted a new version aiming to improve the effectiveness of criminal investigation and prosecution.

xiii. Sustainable and Smart Mobility Strategy (2020): The strategy aims to deliver a 90% cut in emissions by 2050. As part of this strategy, transport by inland waterways and short-sea shipping needs to increase by 25% by 2030.

xiv. Nitrate Directive (1991): The directive addresses the improvement of water quality and the protection of water against nitrates pollution derived from agricultural sources.

4 TOWARDS RESILIENCE FOR WATER MANAGEMENT UNDER CLIMATE CHANGE

Resilience in general describes the capacity of a social-ecological system to withstand shocks without collapsing, to recover, reorganise and transform in anticipation of future stressors (IPCC, 2022). Climate adaptation is crucial for resilience in the context of water systems, as it shows that stressors were experienced or trends determined, lessons were learnt, flexibility despite uncertainty, and stability of the system are worked towards. To help increase resilience, the EEA, the MS, and the Commission have developed a Regional Adaptation Support Tool (RAST). The tool is based on a six-step approach to establish and implement climate adaptation strategies and plans. The approach can also help to identify and evaluate options such as water protection, infrastructure improvements, and changes in water allocation practices.

There is a connection between the pressures of climate change on water quality and quantity and other anthropogenic pressures. The impact of climate change on water depends on the development of other anthropogenic pressures. Ideally, the different analyses outlined in the RAST should be integrated within the analysis needed to produce the RBMP and the programme of measures.

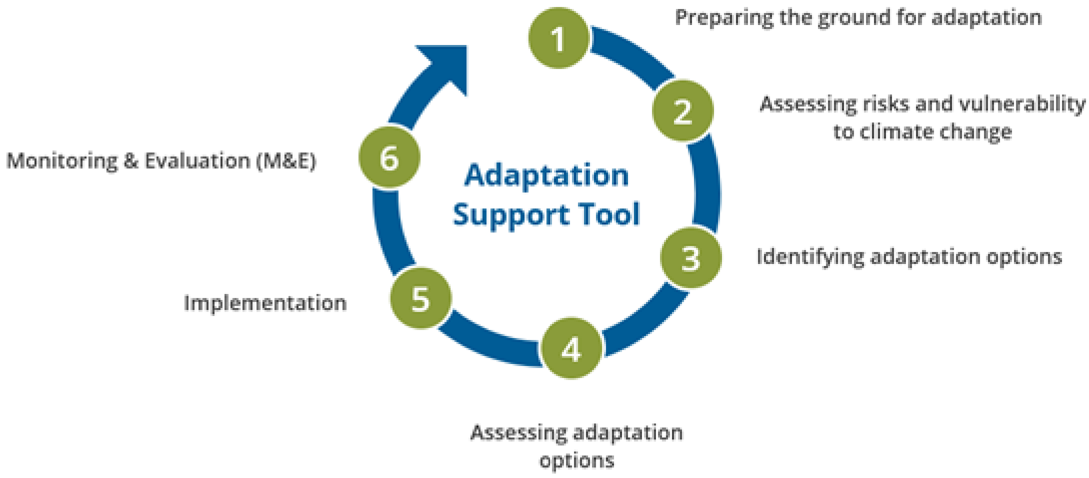

Figure 3: Six-step approach of the RAST for the development and implementation of adaption strategies (Climate ADAPT, 2023a).

4.1 STEP 1: Preparing the ground for adaptation by Strengthening Adaptive Capacity

Step 1 of the Adaptation Support Tool must be understood as the introduction of key elements important to build the basis for a successful adaptation process. This is often linked to other factors related to increasing the adaptive capacity.

Adaptive capacity in accordance with IPCC AR6[12] is the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. Building adaptive capacity and increasing resilience in the context of water management (including flood, water scarcity and drought risk management) requires to:

i. Understand climate-related risks and collect data to improve decision-making and the development of a tailored and sustainable adaptation strategy.
ii. Establish financial mechanisms (e.g., climate change resilience fund) to support and promote the implementation of adaptation measures.
iii. Identify stakeholders and decide on approaches to engage partners.
iv. Work in cross-sectoral partnerships and across administrations.
v. Integrate cross-sectoral adaptation measures and coordination activities with land-use planning.
vi. Include climate change impacts in the RBD awareness-raising activities as part of the WFD and FD public participation processes.
vii. Establish staff training and capacity-building programmes on climate change.
viii. Develop joint or coordinated adaptation strategies in transboundary RBDs.
ix. Communicate to stakeholders about climate change and related economic costs in no-jargon language that can be easily understood.

[12] The Intergovernmental Panel on Climate Change regularly publishes reports about the state of scientific, technical, and socio-economic knowledge on climate change with the latest called Assessment Report 6.

x. Ensure communication and coordination on climate change adaptation issues between different governance levels, geographical areas and policy areas of management within a RBD.

xi. Perform regular evaluations of the adaptation measures and if needed redefine them.

A broad range of stakeholders needs to be involved in adaptation mainstreaming efforts, ranging from national government ministries to sectoral authorities, sub-national governments, industries, and civil society. Stakeholder involvement helps to ensure that policies are informed by practical knowledge and on-ground experience.

It is crucial to provide accurate information and involve stakeholders at an early stage to co-design related policy instruments to face the upcoming challenges in the water sector (Hofman, 2015). This includes policies and strategies aiming to promote more sustainable economies and societies in general but also sectoral policies on, e.g., agriculture, energy, transport and urban as well as spatial planning.

As part of integrated RBM, an important part of adaptive capacity building under STEP 1 is the establishment of RBM plans as well as flood risk and drought risk management plans (Art 3 WFD and Art 7 & 8 FD).

1. Clarify competencies of authorities directly or indirectly responsible for following an integrated approach to climate-resilient water management of river basins and establish an institutionalised process of cooperation (including transboundary) between them (Art 3 WFD, Art 3 FD) as well as across borders in a transboundary context.
2. Establish staff training and capacity-building programmes on climate change issues, e.g. to introduce water managers to climate change modelling, scenarios and projections and establish an ongoing institutionalised exchange of views with climate adaptation experts in other public bodies.
3. Enhance the effectiveness of water governance through capacity-building and collaboration across sectors.
4. Enhance communication and participation with stakeholders to raise public awareness about the need for more responsible water use, adaption to climate change and to understand the relevance of safeguarding e-flows.

4.2 STEP 2: Assessing vulnerability to climate change in water management planning

This is a crucial step that provides a comprehensive and detailed overview of current and future climate risks and related opportunities for water management based on the best available knowledge and different climatic scenarios, catering to uncertainties. This overview must include the expected risks to water resources, ecosystems, the ecological status as well as water-dependent community services and infrastructural assets. It is used to derive the climate change impact and vulnerability assessments (CCIV). However, these assessments normally do not go into detail when it comes to meeting the specific objectives set out in the EU legislation on water. Therefore, more detailed work at the RBD level might be needed and a comprehensive approach is crucial (See also Chapter 9).

Both the FD and the WFD have provisions to include such a CCIV assessment in the planning cycles (see section 5.1 for the WFD and section 6.1 for the FD). Climate risk assessments are available at different geographical levels within the MS[13]. Such assessments are also fundamental for informing the prioritisation of water management and climate action.

Initially, it is imperative to conduct an extensive climate risk and vulnerability assessment, encompassing all potential climate hazards and evaluating their impacts across various sectors in order to promote planned adaptation. This assessment – which water managers should conduct in close cooperation with authorities establishing National Climate Adaptation Strategies and Regional Climate Adaptation Strategies – should move beyond standalone measures but should employ structural stimulation to address specific threats that cut across different sectors. The assessment process should not only adequately account for gradual changes in climate variables such as temperature and sea level, but also for more extreme weather and climatic conditions, and be founded on the most recent and reliable scientific information available. This will ensure that any decision-making process is based on a solid understanding of the potential impacts and risks.

The focus should not solely rely on historical hydrological data and trends. Instead, a range of climate projections and scenarios must be used to support the planning process. This approach allows proactive measures in handling future water fluctuations without posing increased risks to society, the economy, ecosystems, or downstream water users.

An essential aspect involves understanding the influence of climate change on other sectors directly associated with water management (see also section 5.5). This includes considerations such as the impact of climate change on water reuse plans in urban areas, shifts in drinking water production, and the implications for agriculture. It is important to extend the focus beyond the borders of individual rivers and look at the broader river basin level, considering transboundary implications and cooperation.

Identified uncertainties about the precise effects climate change has (in models, scenarios, and estimates), in most cases do not justify 'doing nothing' or continuing with 'business as usual,' simply because these uncertainties are present in the baselines already. With the accumulating effects of climate change, the purported benefits of "wait and learn" appear much smaller than the expected costs of delaying action. The response to deep uncertainty should rather involve identifying "no regret" actions and flexible adaptive solutions as part of active preparations for more decisive action later. For the next RBM cycle(s), the major uncertainties should be properly reassessed when defining the baseline as well as designing and implementing policy measures, including mid-to-long-term adaptation to climate change strategies.

As uncertainty about climate impacts exists, careful management and communication become vital. Effectively communicating these uncertainties is essential for making informed decisions and building resilience and should therefore follow these key principles:

- **Transparency:** Communicate the sources and nature of uncertainties. This includes uncertainties in data, models, and assumptions used in the assessment.

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[13] The latest information reported by MS can be found here.

- **Probabilistic Information:** Express uncertainties in a probabilistic manner, using terms such as probabilities, confidence intervals, and likelihoods to convey the range of possible outcomes.
- **Scenario Analysis:** Acknowledge the diverse range of future scenarios and their associated uncertainties. Presenting a spectrum of scenarios allows decision-makers to consider a range of possible futures.

5. Take the latest and reliable scientific information provided by the IPCC and the Copernicus Climate Change Service into account for models and assessments to ensure that further actions and decisions are based on solid ground.
6. Prior to establishing RBM, FRMP and DRMP, water managers should consider the climate projections made in the national and regional climate adaptation plans and be aware of climate hazards relevant for water management. Assess possible risks in all sectors using water, including cascading impacts on these sectors (this assessment should go beyond stand-alone measures to address climate risks across sectors using regulations, benchmarking, and structural stimulation for one specific threat for one specific sector).
7. Do not only consider hydrological data and trends of the past in the risk assessment but also rely on a range of climate projections (due to uncertainty) and scenarios for improving RBM planning. Such a comprehensive approach allows to sufficiently address future water fluctuations, without creating increased risks for the ecosystem, and the downstream water uses.
8. Make sure to receive information related to the influence of climate change adaptation strategies on related sectors (energy, urban planning manufacturing, inland transport, etc.) and consider their coping-strategies which are directly related to water management.
9. Manage (e.g. perform sensitivity analysis or a scenario analysis) and communicate growing uncertainty carefully. By following a precautionary approach and communicating timely, the worst damage and losses can be avoided.
10. Work along adaptation pathways as a decision-focused approach (see next chapter 4.3).

4.3 STEP 3: Identifying adaptation options by considering different adaptation pathways

In this step, the competent authorities identify relevant adaptation pathways that address both the consequences of climate change and other pressures identified and the related measures to adapt to climate change impacts.

Measures can be both structural and non-structural (e.g. social, behavioural, operational and institutional), such as reusing water, preserving wetlands and a blue carbon ecosystem, increasing the efficiency of water use, saving drinking water by reducing leakages, building dykes, and changing land use practices (IPCC, 2014). Public consultations under the WFD and FD can support the process of identifying these adaptation measures. The identification of adaptation pathways and related adaptation options should be aligned with the national and/or regional adaptation strategies in order to ensure policy coherence. Adaptation pathways may involve a combination of these strategies and therefore, integrating diverse adaptation options can enhance overall resilience to climate change. *Vice versa* the update of these strategies should take into account measures set out in RBMPs and FRMPs.

Adaptation Pathways[14] can help navigate this difficulty and inform the choice of robust adaptation steps. Overall, these pathways are understood as planned but flexible progressions of adaptation decisions, which function as a "road map" towards adaptation objectives wherein different sequential "turns" can be taken, depending on how the future unfolds (Haasnoot, et al., 2013). An adaptation pathways approach recognises that there are often many possible ways to respond to climate change and that a sequential, explorative combination of actions could present the best way to respond (Wise, et al., 2014). Adaptation pathways allow to identify hypothetical future timelines, taking into account changing conditions.

Furthermore, this method identifies how measures are connected to one another, e.g., which measure depends on others being implemented first, or which action rules out some future options. Thus, no- or low-regret actions can be identified, that maintain openness for other adaptation activities and needs in the future. Creating adaptation pathways is a complicated task that requires deliberation, inclusion, and expert assistance. Therefore, this section only provides an overview of different pathway approaches and introduces partners to turn to for designing pathways.

A large **variety of adaptation pathway methods** exist that differ in the context they are applied in, the clarity of the adaptation goal, certainty of responsibilities, and the overall methodological aim. They can be grouped into three clusters (Werners, Wise, Butler, Totin, & Vincent, 2021).

i. **Performance-threshold-oriented pathways methods**: These pathways start from the assumption that the current state of system functioning is satisfactory, e.g., the WFD or FD objectives are currently met. The goal is to maintain the system functioning under increasing climate impacts. When a parameter of system functioning drops below a certain quantifiable point, e.g., water depth to enable navigation, a measure is chosen within a defined temporal "window of action" to adapt. Thus, a pathway under different future scenarios can be drawn based on modelled environmental changes in an "if not A, then B or C" fashion. These pathways function in a data-rich context, where the goals are agreed upon and the responsibilities now and in the future are clear.

[14] A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation (IPCC, 2022a).

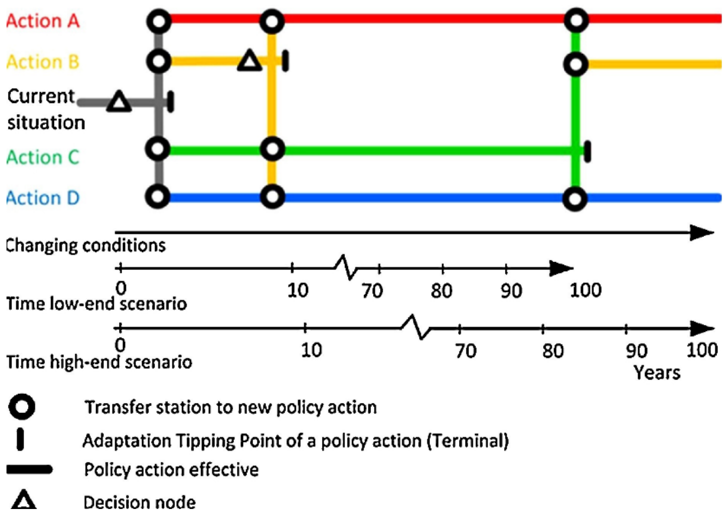

Figure 4: A schematic depiction of a Performance-Threshold Pathway as used in the Dutch Delta Programme (Deltares, 2023). The timeline runs from left to right, under different change scenarios. Lines are different implemented effective actions. Circles show points to make a new policy decision, and dead ends show the end to a window of action, after which a measure is no longer effective for adaptation.

ii. **Multi-stakeholder-oriented pathways methods**: This cluster focuses very much on the process of pathway development, which is under the inclusion of different stakeholders. Thresholds are not defined as environmental parameters but rather as changes that are relevant to the people. This is done to increase acceptability, build the adaptive capacity of the community by involving them in planning processes, and to harvest local knowledge on e.g., what happens exactly when a specific area floods and what needs to change.

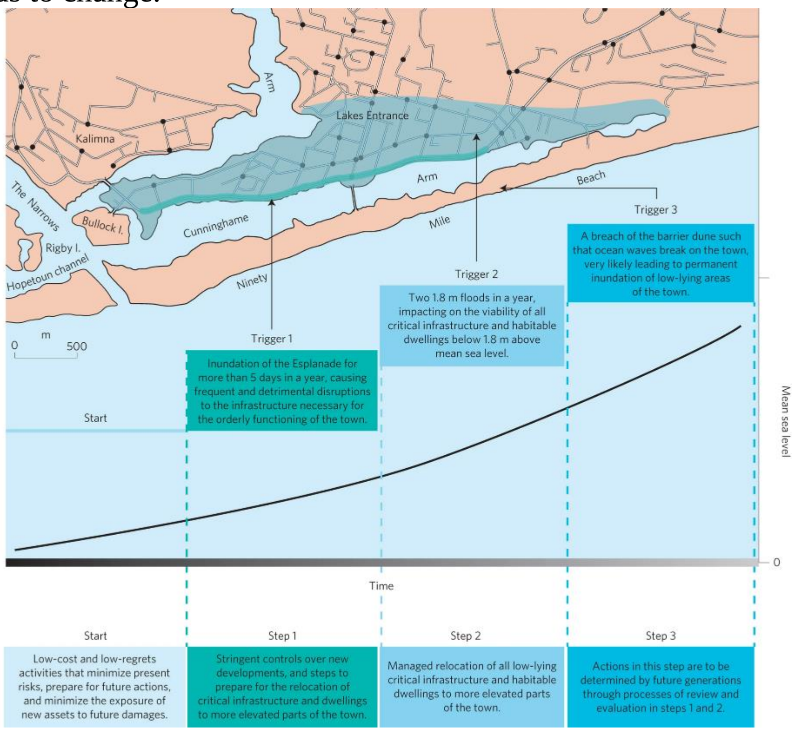

Figure 5: An example of a Multi-Stakeholder Pathway on coastal adaptation to rising sea levels (Barnett, et al., 2014). The timeline runs from left to right, and different stakeholder-defined triggers mark when certain steps have to be taken, leaving room for future generations to identify the best steps in their time.

iii. **Transformation-oriented pathways methods**: In contrast to the other clusters, these pathways start from the recognition that deeper change is necessary to successfully adapt in the long-term. This deeper change could comprise trying to tackle the root of adaptation issues and changing framework conditions such as institutional arrangements and decision-making processes. Transformation pathways do not start from the present and identify points where adaptation is needed, but rather define a future goal that may differ significantly from the present on many levels, and back-cast the necessary steps towards the present. Thus, short-term, and long-term actions can be identified.

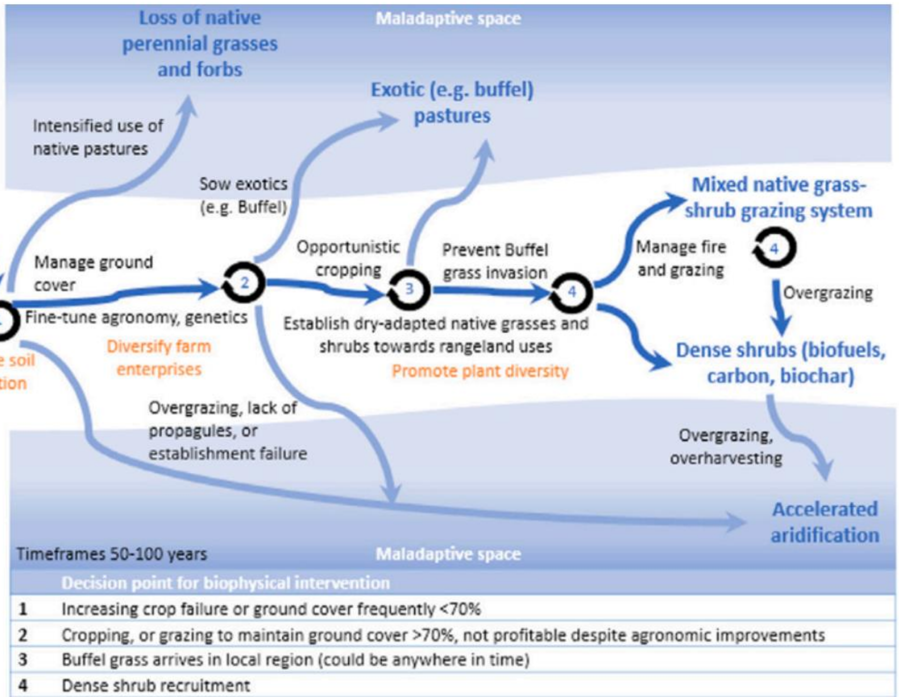

Figure 6: An example of a Transformational Adaptation Pathway for restoring a native ecosystem on Farmland (Prober, et al., 2017). The timeline runs from left to right, deep blue are desirable outcomes and light blue maladaptive outcomes drifting into the maladaptive space. Circles are decision points when action has to be taken, the orange text identifies actions to increase resilience.

Aspects of these three clusters can be combined to fit a local context and form an idea of how to reach adaptation goals. If correctly applied, pathways provide transparency and planning security to stakeholders, which enables stakeholders to take necessary adaptation actions themselves and encourages continuity of investment over longer periods of time. Furthermore, a variety of strategies and actions are considered, which allows choosing the most cost-effective adaptation paths (Marks, Liu, & Krans, 2021).

The OECD has developed an analytical framework that can support the design of strategic investment pathways. It can serve as a source of inspiration and a basis for discussion on the strategic planning of water-related investments in MS (OECD, 2022b).

11. Align water planning instruments closely to national and regional climate adaptation strategies.
12. Work along adaptation pathways as a decision-focused approach. An adaptation pathways approach recognises that there are often many possible ways to respond to climate change and that a combination of actions, some of which are taken now and some that may be taken in the future, could present the best way to respond.

13. Prefer adaptation options which are robust in various sets of climate change and land use scenarios as well as adaptation pathways and do not commit too firmly to one particular projection of the future by building flexibility into your water management and land use systems.
14. Prioritise equitable access, efficient water use, and maintain e-flows to scarce water resources in new strategies within a river basin, recognising the unequal distribution of climate change impacts and disparities of adaptation capabilities.

4.4 STEP 4 Assessing adaptation options

This step comprises the assessment and ranking of the identified water management/adaptation options. Such an assessment must include criteria of criteria effectiveness, feasibility and costs to reach the specific objectives set out by the WFD and FD[15] but also aspects like climate proofing and just resilience[16].

Climate proofing refers to the process of assessing and modifying policies, plans, programmes, and measures to make them more resilient to the impacts of climate change but still reaching the water management objectives (e.g. good status). The goal is to ensure that these measures are robust and effective in terms of changing climatic conditions and to avoid maladaptation. A detailed approach of how to perform climate-proofing is found in Chapter 10.

Maladaptation includes adaptation actions that have negative side-effects or outcomes, directly or indirectly, at a later point in time or in other areas, sectors, or parts of society. Such consequences are usually unintended. Maladaptation may compromise the ability of a water body to meet GES/P because an action inadvertently changes the physico-chemical or hydromorphological elements in a water body, for example by modifying upstream or downstream flow conditions. Focusing on a single scenario instead of exploring a range of possible future climates can result in under-design (and a risk of a stranded asset) or over-design (with unnecessarily high costs): flexible and adaptive designs are less likely to result in maladaptation. Some actions may result in increased CO2 emissions. Others may not take into account longer-term consequences.

Maladaptation is formalised in the EU by the 'Do No Significant Harm' (DNSH) principle. The principle is relatively new and applies to private and public finance. The aim is that MSs improve their capacity to apply the DNSH principle to public investments from EU and national funds and programmes, including from the Recovery and Resilience Facility (RRF). MSs need to provide a DNSH assessment for each and every measure (i.e. each reform and each investment) of their Recovery and Resilience Plan (Article 14 of the RRF Regulation), including water management measures.

Just Resilience aims at reducing the unequal burden of climate risks and ensuring equity in the distribution of benefits (and burdens) of adaptation (e.g. Recognising and addressing

[15] See also WATECO (2003)

[16] The concept of 'leaving no one behind' is a key element in recent and forthcoming EU policies related to climate adaptation, including the European Green Deal policy package and the EU Mission on adaptation to climate change.

gender-specific vulnerabilities and capacities in adaptation planning). Article 9 in combination with Annex III of the WFD allows to consider social aspects in the development or definition of water pricing policies. Just Resilience aspects should also be considered in the development of Flood Risk Management and Drought Risk Management Plans.

Meaningful engagement of vulnerable groups in these processes is also essential. When doing a cost-benefit analysis of flood risk reduction measures, the consideration of social welfare including individual social vulnerability[17] through relative impacts on consumption is important to reduce vulnerabilities for the poorest (Kind, Botzen, & Aerts, 2020).

Example 2: Social Vulnerability Assessment for Flood Risk Analysis

In the municipality of Ponferrada in Spain a methodology for analysing social vulnerability to floods was developed by integrating and weighting exposure and resistance indicators. The indicators include population density, evacuation time, emergency service personnel ratios, health staff, and qualitative measures. To weigh each of those indicators, an Analytic Hierarchy Process was conducted and experts from various fields were involved. The results provide a detailed social vulnerability map on an urban plot level, aiding flood risk planning and management in terms of selecting and placing measures. In order to allow replicability of the methodology, the majority of data used for the calculation of the indicators comes from open public data sources (Tascón-González, et al., 2020).

15. Make sure that water management adaptation measures and plans are climate-proofed, besides ensuring that they contribute to reaching the set objectives. When choosing between alternative climate adaptation options for water management, preference should go to solutions that prevail above others in alternative climate evolution scenarios.
16. Ensure that resilience-building efforts are fair and just, providing equal opportunities and resources for all communities, particularly marginalised or vulnerable groups.

4.5 STEP 5 Implementation

The fifth step consists of putting into effect the preferred climate adaptation options in the context of the RBMPs, FRMPs or DRMPs. There is a broad portfolio of instruments available that can be used to implement adaptation measures (Climate ADAPT, 2023a):

i. Legal instruments (laws, regulations, decrees, 'soft law' such as standards)
ii. Economic instruments (funding, taxes, fees, public procurement, grants, loans, market-based)
iii. Informational instruments (studies, databases, information campaigns, advice, supervision, training of staff, guidance and work aids, disaster education to raise awareness of community people, events, websites)
iv. Partnership instruments (Public Private Partnership Agreements, voluntary agreements, collaborative projects)
v. Hybrid strategic/planning instruments (plans, strategies, programmes, planning instruments)

[17] Social vulnerability is distinguished between immediate vulnerability addressed through short-term interventions (e.g. emergency response measures during and after a disaster) and a form of vulnerability, which changes over time due to factors such as economic development, changes in infrastructure, social policies, and community resilience-building efforts.

Implementation of adaptation measures for the water sector might also require action beyond the water management sector. Therefore, it is essential that mainstreaming water adaptation planning occurs at all levels of sectoral policy-making including, e.g. defining the policy agenda and designing legislations, strategies, and instruments (such as programmes and plans). The coherence of different policies with common water-oriented goals is essential to minimise conflicts, avoid trade-offs and foster mutual synergies. For example, if a new infrastructure project might have significant impacts [e.g. directly on the hydro morphology or indirect via changing soil conditions (e.g. soil sealing[18]) on local water bodies], it is important that water-relevant aspects are included from the beginning of the planning process. Considering water resilience already from the initial phases of a project not only prevents expensive adaptation measures from being implemented afterwards but also leads to positive linkage effects (e.g. water-related ecosystems provide benefits in terms of climate mitigation and reduce disaster risk from flooding) (Climate ADAPT, 2023a).

Example 3: VigiEau: An innovative solution to communicate on drought in France.

The VigiEau website was launched in 2023 by the French Government to support the implementation of its drought risk planning and to support citizens' and businesses' understanding of and provide information on drought restrictions. Homeowners should thereby be encouraged to reduce their water usage in order to limit the impact of droughts and to avoid fines. It provides a colour-coded map of France showing the different communes and departments where water usage restrictions are currently applied. The restrictions are split into five categories: Watering gardens and green spaces; Filling swimming pools and playing water-based games (e.g. water slides); Cleaning your home and car; Using water for a fountain; Impact on building works. Citizens can research by entering their home address, which of these categories are currently in place in their area. VigiEau allows the French government to render the type of drought management measures taken more transparently and consistently at the regional level while leaving implementation decentralised.

Example 4: The Blue Deal in Flanders

Facing water scarcity and drought risks, Flanders has launched the Blue Deal programme to address these challenges. The Blue Deal addresses some specific vulnerabilities of Belgium, among them the inability of soil to absorb precipitation due to land sealing, and one of Europe's highest water exploitation per capita. 13 projects with a total budget of 343 million Euros invested by the regional Government of Flanders have been launched. The goal is to increase the water availability to restore the sponge function of wetlands, create storage for alternative water resources, reduce leakage losses and support innovative projects. Furthermore, the water demand should be reduced by using water more efficiently in order to retain water longer upstream and raise the amount of available water. A task force led by the Flemish Minister of Environment oversees the progress, ensuring effective implementation, and the participation of stakeholders, including companies, farmers, citizens, and governmental bodies.

Example 5: Incentivise a proactive attitude on resilience.

ARERA – the national economic regulatory authority in charge of the water and sanitation sector in Italy – has recently introduced a specific mechanism aimed at improving resilience in its regulatory mechanism dedicated to enhancing the quality of water resources, environment and provide service.

[18] See also the Soil Strategy.

The Italian technical quality mechanism is based on a number of KPIs, so-called, macro-indicators, addressing the main targets in terms of preserving water resources when providing the service:

i. water losses;
ii. service interruptions;
iii. water quality for users or preserving the environment;
iv. adequacy of sewage systems;
v. water treatment sludges;
vi. quality of treated wastewater

Macro-indicators have been chosen with strict output-based criteria and with a particular attention to the principle of technological neutrality. ARERA quality regulation fixes targets for each operator depending on its specific starting situation (higher targets for operators more distant from an optimal situation) and associates an award/penalty mechanism, according to the fact that targets have been reached (or not, in which case the operator gets a penalty) for each macro-indicator. In the first 4-years of implementation, the Italian regulator has provided awards for an overall 265 million Euros and penalties for 24 million Euros.

Lack of financing is often an issue in the implementation of measures and plans. Under the EU mission for climate change adaptation an overview of EU and national funding sources is provided.

17. Align RBM plans to climate change adaptation strategies and involve/inform relevant stakeholders. Ensure that water managers are aware of other sectoral climate adaptation efforts to consider them at an early stage.
18. Involve diverse stakeholders, including local communities, marginalised groups, and indigenous peoples, in decision-making processes related to resilience planning and implementation. Their awareness and cooperation are crucial in the practical reality.
19. Building on the risk assessment, climate adaptation should be mainstreamed into all decision-making and policy processes relevant for integrated water management, with the policies listed as informing the basic measures in the PoM for a RBMP at its core (WFD, Art 11).

4.6 STEP 6: Monitoring & Evaluation

The final step involves continuous monitoring and evaluation of the effectiveness of the plan over time. This includes tracking the implementation progress, assessing the outcomes and impacts of the adaptation measures, and regularly adjusting the plan as needed based on the results of the evaluation. Both, the WFD under Annex V (1.3. and 2.2) and Art 13(4) in connection with Annex VII(B) and the FD under Art 7 in connection with Annex A(B) provide provisions for monitoring schemes which could be integrated into such a monitoring and evaluation concept.

In conclusion, while the WFD and the FD precede the Commission's Guidelines on National Adaptation Strategies, they already foresee administrative steps which are directly relevant to climate adaptation. Importantly, as set out above, water planning instruments must be closely aligned to national climate adaptation strategies. Water managers are well advised to consider competing climate change scenarios to account for uncertainty as recommended in their respective national climate adaptation strategy.

20. Monitor and evaluate the processes of mainstreaming that help policymakers determine if the desired outcomes are achieved. Evaluating also enables the timely adjustment of policies if needed.
21. Monitor the impact of measures taken to address the impact of climate change on water management in order to enable the improvement of measures over time.
22. Build the monitoring and evaluation scheme on existing provisions set out in the WFD (Art 8.) and FD (Annex A II 1).

5 WATER FRAMEWORK DIRECTIVE AND ADAPTATION

The WFD was adopted eight years after the UN Framework Convention to Combat Climate Change (UNFCCC, 1992), thus the acute need to reduce GHG as well as the impacts of climate change were already well known. Article 1 of this Directive indicates that its purpose is to protect and, where necessary, restore water bodies to reach good ecological and chemical status, and to prevent a deterioration in status, while *inter alia* establishing a framework to contribute to mitigate the effects of droughts and floods. The underpinning rationale and process of the WFD are amenable to contributing to adaptation. In particular, the integrated approaches to land, water and ecosystem management, combined with the cyclical review of progress, are all consistent with adaptive management. Focusing on the resilience of healthy aquatic ecosystems to changing and degrading conditions, for instance, provides a cost-effective and relatively easy way to achieve adaptation.

It should be kept in mind that climate change impacts in one part of a river basin can have implications for the achievement of WFD objectives in other parts. Therefore, regional and (where applicable) international cooperation plays an important role. Please check the recommendations in Chapter 9 on the need to develop joint and coordinated adaptation strategies in RBMP of international RBDs and coordinate cooperation for marine waters, where the connectivity of river basins with coastal and marine waters requires national and international adaptation strategies.

Some of the RBM steps are considered more critical than others with respect to the ability to prepare for climate change, especially in the short term. Essential components for planning are:

i. Ability to identify emerging change through monitoring and modelling to adapt the necessary assessment of characteristics, types, reference conditions and status of water bodies,
ii. Ensuring that the scale of climate change impacts and projected future anthropogenic pressures and risks is understood.
iii. 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.
iv. Secure funding and capacities for the implementation of plans

These parts of RBM should be the focus of MSs when considering how to deal with climate change.

5.1 Pressure and impact assessment

MSs are required, under Article 5 of the WFD, to review all pressures on water bodies, including the impact of human activity, (e.g. point and diffuse source of pollution, abstractions), on the status of surface waters and groundwater (see Annex II of WFD for technical specifications), but also pressures resulting from climate change. The considerations outlined below relate to climate change induced pressures and impacts.

Most of the WFD pressures are sensitive to climate change, whose main impacts are summarised in Chapter 2. The direct effects of climate change, such as increased air and water temperatures and higher frequencies of extreme meteorological events, can interact with human responses to climate change, known as 'indirect effects'. These 'indirect effects' can sometimes have a greater impact than the direct effects of climate change.[19]

5.1.1 Surface Water

Evaluate how climate change affects surface water bodies. Consider Climate change effects such as increased water temperatures, altered precipitation patterns (amount, intensity, frequency and type), extreme weather events, and rising sea levels have a direct impact on surface water bodies. In many cases, the effect depends on the development of different sectors putting pressure on the water bodies. These changes can impact water quality, quantity, and ecosystem health (See also Chapter 2). The following steps may be useful:

i. **Identification and assessment of impacts** on water bodies: Estimate identify/assess/model the combined impact of climate change in and the development of different anthropogenic pressures on the ecological status or potential and chemical status of surface water bodies as well as on the quantitative and chemical status of groundwater bodies.

ii. **Assessing pressures and impacts**: Various potential climate change scenarios should be considered in the assessment of pressures and adaptation measures covering the entire river basin across borders. It may be supportive to develop models that project the potential future state of water bodies under various climate change conditions and sectoral developments[20]. This could involve scenarios like increased drought, heavier rainfall, altered flow patterns, and changing temperature regimes combined with the projected development of different sectors. It is recommended that you liaise with your national meteorological services to identify those climate projections that you should use for your assessment.

iii. In designing adaptation strategies, align strategies with the projections in national adaptation strategies or plans based on pathway approaches at the regional and local levels (see section 4.3). This could involve modifying water management practices,

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[19] For example, changes in land-use practices in response to climate change, such as adjusted cropping regimes or a shift to renewable hydroelectricity to mitigate climate change, can very strongly affect freshwater ecosystems (Brosse, et al., 2022).

[20] In this context it is also important to evaluate the dynamic relationships between surface water and groundwater together with the ecosystems connected to them.

developing NBS to handle extreme events, restoring habitats, changing agricultural practices and ensuring e-flows.

Example 6: Nutrient Emissions Modeling supporting climate resilient Danube River Basin Management

In drafting the updated Danube RBMP (DRBMP 2021), coordinated by the International Commission for the Protection of the Danube River (ICPDR), an approach was taken to tackle climate change impacts on water quality. The DRBMP 2021 focuses on five significant water management issues, which are the main pressures that affect the water status, including the effects of drought, water scarcity, extreme hydrological phenomena, and other impacts. The use of the MONERIS model at the basin-wide level enabled an estimation of nutrient emissions, identifying sources and pathways contributing to the total emissions.

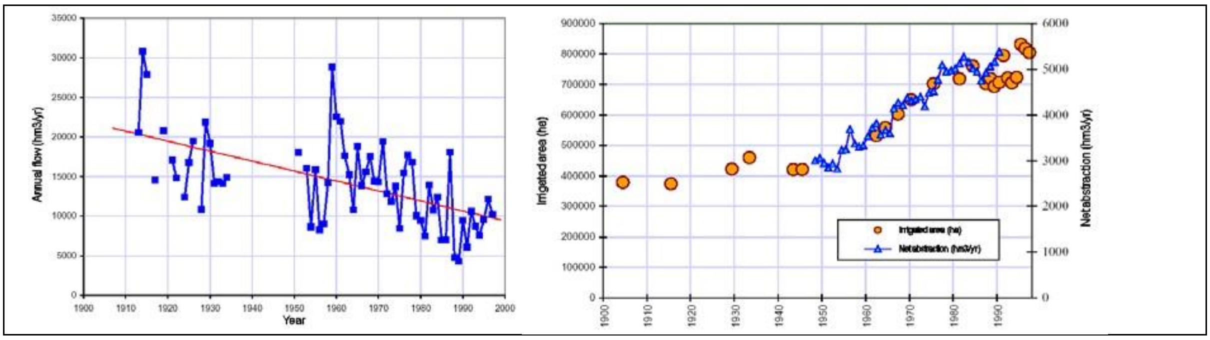
The model, applied at the sub-catchment scale, assessed nutrient emissions under extreme "dry" and "wet" conditions, incorporating climate change scenarios and measure implementation. The results for Romania showed that for low water conditions (dry situation), lower nutrient emissions are expected, forecasting a 7.5% (N) and 10% (P) emission reduction of the total nutrient emissions compared to the vision scenario. On the other hand, in peak runoff years (high waters), runoff and potentially soil erosion are more important, leading to increased diffuse emissions. Thus, in the case of maximum discharge conditions (wet conditions), an increase compared to the vision scenario of emissions by 23 % (N) and 20.2 % (P) of the total nutrient emissions is expected.

Observed hydrogeological changes should be formally linked to climate change in a standardised manner to enable Europe-wide comparisons. Guidance should be developed for implementation across all water body types and should take into account the issues outlined above. An example of such guidance is the development of calibrated assessments of observed weather and climate-related events and the identification of any changed risk of such events attributable to climate factors (WMO, 2011).

An example from the Ebro River in Tortosa, Spain, highlights the need to provide comprehensive guidance and common standards to facilitate the robust attribution of observed hydrological impacts in a way that enables an assessment, reporting, and comparison between catchments, regions, and countries.

Example 7: 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 occurring.



5.1.2 Groundwater

In terms of a risk assessment, it is necessary to carefully analyse the temporal development of the renewed groundwater volume which is highly dependent on the effects of climate change on precipitation, temperature, evapotranspiration, changing snow and ice regimes, etc. and land use/land cover regulating the groundwater recharge conditions. This is typically achieved by assessing groundwater quantitative trends through precipitation, piezometric and evapotranspiration measurements either at national or catchment scales. An essential parameter in the assessment of the sustainable use of groundwater, and thus the risk assessment, is the available groundwater resource, which includes both groundwater recharge and the groundwater needs of aquatic and terrestrial ecosystems that depend on groundwater.

For monitoring programmes to identify climate-driven impacts on groundwater quantity, changes must first be detected/observed, and they must then be assessed as to whether they were caused by climate change or some other influence. The process of determining whether changes have been caused by climate change is called “attribution” and has been defined by the IPCC as ‘the question of the magnitude of the contribution of climate change to a change in a system’ (Cramer, et al., 2014; IPCC, 2014). There are large uncertainties in attributing trends in groundwater quantity to climate change robustly (IPCC, 2014), mainly due to limitations in the spatio-temporal coverage of groundwater monitoring networks, abstraction data and numerical representations of groundwater recharge processes. Attribution of observed trends to climate change is often a tedious task which needs to be approached in a systematic manner. High quality and appropriate meteorological and groundwater data is required to facilitate unambiguous attribution, as well as a clear understanding of the processes by which meteorological changes can impact groundwater quantity. Such processes may be non-linear, be subject to impact thresholds or be spatially and/or temporally heterogeneous, e.g. long lag-times.

Groundwater monitoring and assessment is primarily concerned with attribution of long-term annual and seasonal trends. However, **no EU MS appears to have in place a formal, standardised, and specific process for attributing observed groundwater quantitative and qualitative changes or their impacts to climate change**.

The identification of groundwater bodies that are either vulnerable or resilient to climate change impacts is another important element of adaptation planning. Approaches classifying groundwater bodies typically use a modelling approach and a combination of meteorological and hydrogeological criteria. The temporal dimension is an important aspect that needs to be considered when assessing vulnerability, as some groundwater bodies with low storability and direct recharge may be vulnerable to short-sharp droughts, while other more buffered groundwater bodies may be more vulnerable to multi-year or long-term droughts. Some groundwater bodies are multi-aquifer formations which should be considered in the vulnerability assessment and coastal aquifers are very often vulnerable to both, the decrease in recharge, the increase in pressures and the resulting chemical degradation due to saline intrusion.

23. Put in place a formal, standardised, and specific process for attributing observed water quantitative and qualitative changes to the impacts of climate change. In so doing, assess the change of drivers and pressures on groundwater bodies due to climate change over a range of timescales, considering along with direct and indirect drivers of water scarcity influences but also consider adapting activities to climate change.
24. Consider climate change in the economic analysis according to Article 5 WFD (and Annex III) in the context of recovering the cost of water services (WFD Article 9) and for defining measures in the programme of measures. To perform a proper climate water risk assessment as part of the pressures and impact assessment and the economic analysis, consider the long-term water supply and water demand forecasts and scenario, and subsequently, the Costs-Effectiveness-Analysis underpinning the set of measures in the PoM and the investment planning/forecasts.

5.2 Status Assessment

5.2.1 Surface water body typology, reference conditions and classification

The implementation of the WFD is based on objective and transparent criteria and procedures as agreed in the CIS, 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 all quality elements included in the definition of ecological status (biological, physio-chemical, hydromorphological), this does not affect the principles of water status assessment, which remains valid. However, we must ensure that the WFD approach remains valid and even optimised to protect aquatic ecosystems for the coming decades alongside pervasive climatic change.

According to the WFD, the overall surface water status is determined by the QE in the poorest status of its ecological status/potential and chemical status. Biological Quality Elements (i.e., fish, invertebrates, phytoplankton, etc.) are the key components in the classification of surface water bodies and they indicate the impact of multiple pressures. This very sensitivity of the biological species to changes in their environment makes the WFD classification system susceptible to the impact of climate change. The challenge is therefore adapting the approach to status assessment in the context of climate change while maintaining focus on implementing measures to tackle key pressures such as nutrients, other pollutants and hydromorphological alterations to achieve environmental objectives. The fundamental drivers of changes are temperature, hydrology, and sea level rise. Some key thematic impacts on aquatic systems include altered morphology, hydrology including floods, droughts and disrupted seasonality of flow as well as altered nutrient export, delivery and mineral cycling. Also important is **the threat of increased salinisation from droughts and saline intrusion**. In addition, the changing in the timing of the seasons can lead to a phenological mismatch, for example between prey and predators with implications across the food chain or changes in community composition. Changes in environmental conditions could also enhance **the settlement of invasive species** and affect the structure of the indigenous community and native biodiversity.

Surface water bodies are characterised into water body types by a set of obligatory factors and descriptors for both systems A and B in Annex 2 to the WFD (e.g., topographic, geological, physical, hydrological). System B has the option of using additional natural factors (e.g., water depth, mixing characteristics, background nutrient status). A number of these factors are climate-sensitive. Water bodies could therefore migrate from one type to another because of gradual climate change or a sequence of extreme events (Nõges, 2009).

If the type of some water bodies will permanently change as a result of climate change despite all additional measures implemented, these water bodies should be assigned to an appropriate type within the existing typology and the corresponding reference conditions applied to them. If there is no possibility for re-assignment to an existing type, a new type could be created or the existing type updated with its specific reference conditions and class boundaries. However, in this case, it is important to verify whether the new or updated class boundaries need to be intercalibrated. Modelling can also be used to predict likely changes, examining similar types at warmer latitudes for example.

According to Article 5(2) WFD, the review of the characterisation of water bodies should take place every six years. In some cases, it may be necessary to refine the definition of types, as indicated in System B (e.g. using more climate-sensitive parameters like channel morphology, air temperature, and precipitation) in order to define additional types. See Table 2 for a list of typology parameters listed in either system A or B (Solheim, et al., 2019) along with estimated sensitivity to climate change. However, before changing the typology and associated reference conditions, all other options and measures should have been exhausted in order to avoid lowering the ambitions of the environmental objectives.

One example of such changes is the increasing background loading influx of humic substances to northern rivers and lakes (the so-called browning), which may cause them to change from clearwater types to humic types. However, increased browning can also result from catchment land use change altering ecosystem functioning representing a challenge to partition global, local and regional drivers into what might be defined as typological or pressure-driven change (Asmala, et al., 2019), which should lead to the implementation of suitable measures and not a change in typology. Changes in typology can be more prevalent in specific environments, for example, alteration of natural turbidity is particularly important for water bodies with clay deposits or glacial silt. Ecosystems of some types of water bodies, e.g. large shallow lakes and rivers in arid regions, are more physically controlled and thus more sensitive to climate change. More information on this example and other examples related to changes in the natural conditions of water bodies are introduced in ANNEX II.

Typology factors	Rivers	Lakes	Transitional	Coastal	Relevance for climate change
Size		+			
Mean depth		+	+		

Altitude					
Region					
Geology: Alkalinity	+	+			
Geology: humic substances (colour)	+++	+++	++	+	Northern Europe mainly
Flow	+++		+		
Residence time		+++	++		
Mixing		+++	++	++	
Temperature	+++	+++	+++	++	
Background nutrient status	+	+	+		
Salinity/chloride/conductivity	++	++	+		
Substrate composition	+++	++	++	++	
Water level fluctuation		+++			
River width	+++				
Morphology/shape	+++	++	+		
Solids/turbidity (natural)	+++	++	+		Clay deposits/ glacial silt
Precipitation	+++	++			
Tidal range	+		+		
Wave exposure		+	++	+++	

Table 2: Main typological factors in use for lakes, rivers, and coastal/transitional waters (System A & B typology factors) and their sensitivity to climate change

For water bodies negatively affected by climate change, more intensive monitoring should be implemented to better understand the pace and mechanisms of such a change, in order to ascertain also whether such changes gradually modify the natural conditions of the water body such that a re-allocation to a new water category or type becomes appropriate.

In fact, a robust long-term monitoring network of reference sites, i.e. with no or very limited anthropogenic impact, with sufficiently long series of data would be the most direct way of detecting responses of water bodies to climate change impacts. In practice, MS use slightly different criteria for selecting reference sites. The use of the best available sites instead of real reference sites should be marked as such and defined as an alternative benchmark (e.g. good status) (see Guidance document No 10, 2003). If the conditions at reference sites change, it would be important to find out the causes and decide whether the site can still be used or not as a reference site.

Many biological systems are already showing thermally and hydrologically induced changes, although disentanglement from other anthropogenic pressures can be difficult. Therefore, climate change signals may confound the analysis of trends expected from PoM implemented in WFD RBM cycles.

It is important to account for inter-annual and decadal natural climate variability, often identifiable by examining teleconnection indices such as the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO). Therefore, status definitions should be sufficiently long to accommodate natural variations within types. Given the short duration of many monitoring programmes, short-term tendencies in ecological status should be interpreted with great caution, although climate-driven dramatic shifts are also possible (e.g. from droughts or floods). Other data on biological composition or supporting elements may prove to be useful in extending the time series to examine change.

If the intensified monitoring is giving scientific evidence of climate change having a direct negative impact on one or more quality elements, additional measures shall be taken to achieve original objectives. If despite additional measures, climate change is causing irreversible changes in the natural conditions, the water body could necessitate re-allocation to another existing type as mentioned above.

Anytime there is a significant risk that climate change may compromise the achievement of the WFD objectives, this should be noted in the RBMP and communication with stakeholders and the general public should take place since it is relevant information to river basin managers and may assist in considerations of optimisation of scarce resource use between locations and objectives.

25. Include reference sites in surveillance monitoring programmes to understand the extent and causes of natural variability and the impact of climate change (see point 1.3.1. Annex V to the WFD).
26. Distinguish between Climate Change pressures and other anthropogenic pressures for the purposes of effective management, maintain long-term, high-resolution, homogeneous and quality-controlled meteorological, hydrological, water quality and biological monitoring systems. Sites having a long history of monitoring should be prioritised.
27. Consider using re-analysis – a blend of measured and modelled data to produce a complete data record – for example use the data available at the Copernicus Climate Change Service and Climate Date Store if sufficient long-term meteorological monitoring data is not available.
28. Use climate indices (e.g. North Atlantic Oscillation) 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.
29. Undertake periodic reviews of conditions and pressures at reference sites to assess whether the site can still be used as a reference.
30. Be aware of the challenges associated with the attribution of environmental changes to anthropogenic climate change and avoid over-interpretation of observed trends.

    Focus on how climate variability and change will interact with pressures from human activities to better plan measures. In many cases, climate change would aggravate the impacts of other human pressures, e.g. nutrient pollution, and more comprehensive measures would be needed to counteract the additional impacts caused by climate change.

5.2.2 Groundwater bodies

The status assessment (both quantitative and chemical), the establishment of threshold values and the assessment of groundwater trends and trend reversal, according to WFD Annex V and its daughter Groundwater Directive (GWD), are tackled in detail by CIS guidance document No 18, which proposes a set of different tests. **The reflection of climate change effects within the groundwater status assessment is rather related to the consideration of the relevant climate change-affected pressures and indicators than to the assessment methodology itself.** For example, consideration of groundwater temperature as an indicator of changing biological and chemical processes could be relevant.

WFD's environmental objective for good groundwater quantitative status is to ensure a balance between natural recharge and abstractions and recharge (Article 4.1.b.ii). In addition, Annex V 2.1.2. (good status requirements) specifies the need for avoiding groundwater level alterations leading to any damage to groundwater-dependent aquatic or terrestrial ecosystems or alterations of flow directions resulting in saline or other intrusions.

Although the WFD lays down the groundwater level as the metric for quantitative status assessments, alternatively spring flow/discharges, baseflows of rivers and water balance assessments are recommended. A groundwater quantitative status assessment is undertaken by all MS to some extent in the form of spring flow measurements, in some countries for a significant area of groundwater bodies, e.g. Austria. However, several countries also calculate the volume of groundwater within groundwater bodies in addition to the spring discharge volumes. These methods use a range of approaches, such as usable gross resource volume estimation or sustainable yield. Others also calculate groundwater contribution towards surface water ecological flows, typically using modelling approaches (Ireland, for example).

Applying groundwater level assessments might also need to consider the impacts of sea level rise due to climate change, which appears to be considered by MSs on a risk-based approach. Countries that are likely to be significantly impacted by sea level rise already employ detailed monitoring and assessment methods (e.g. Belgium, Malta, Netherlands, Portugal). In other MSs, this characterisation is still in the research domain (Ireland). For other countries, such monitoring can be ruled out for technical reasons, such as in parts of Sweden where post-glacial isostatic rebound is currently outpacing measured sea level rise.

The definition of a good quantitative status is focused on long-term issues, thereby implicitly neglecting short-term effects, i.e. increased seasonal variation. This may need to be examined, in particular when considering that e.g. groundwater dependent ecosystems can be significantly damaged even by short-term drought events.

5.2.3 Protected Areas

Changes in the abiotic conditions of habitats (e.g. changes in water tables) can change the status of protected areas such as NATURA 2000. Therefore, “special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water” is needed.

The relevance of climate change on drinking water abstraction areas regarding Article 7 is related to the impacts of more frequent and intense pollution events or higher variations of water available that could arise from extreme weather events, altered (flash flood) runoff, and increased water temperature. The pollution of water bodies or high alterations in the available water amount does not only have an impact on the security of drinking water supply but further impacts ecosystems in the protected area (e.g. dwindling springs, low ground- and surface water levels).

The damage done to an ecosystem can in turn lead to long-term consequences, such as the reduction of the natural self-purification effect of water, which can lead to higher treatment costs. Low self-purification can also be directly related to low stream flows if structures to provide sufficient water levels for agriculture or shipping are present. By implementing protective measures in these zones, such as stricter controls on pollutant discharges, monitoring and land use management, the vulnerability of protected areas to climate change-induced stressors can be reduced.

In the context of addressing climate change impacts on aquatic ecosystems and water resources, the Natura 2000 network can play a significant role as a complementary measures. The efforts of Natura 2000 with the provisions of the WFD, can support biodiversity conservation, improved water management, climate change adaptation and resilience of protected areas. The Commission also published a Guidance Document about adapting Natura 2000 areas to climate change where further information is provided.

5.3 Monitoring

5.3.1 Monitoring of surface water

Whilst monitoring programmes under the WFD are generally not designed to identify and monitor all anthropogenic pressures like climate impacts, all additional long-term monitoring programmes will inherently contribute to the detection and understanding of any climate change signals. Also, the assessment of seasonal variations becomes more important in rivers when a river changes from perennial to temporary because of climate change. Such rivers start to fall dry over summer which has a huge impact on the biota. Monitoring becomes more difficult though, because the timing of sampling becomes more critical and suitable time windows become smaller. Equally, sampling during flood episodes can reveal pollutants introduced by flood-related run-off and should therefore be carried out if it can be done safely. Similarly, additional monitoring besides flooding and drought events should also be carried out in the waterbodies downstream, as transitional and coastal waters.

It is very important to take a consistent and long-term approach. Monitoring programmes should be planned carefully with a long-term perspective and carried out consistently by preventing major changes in the station network and/or in the implemented methodologies. It is very important to avoid abandoning monitoring stations which already have a long-term consistent record. Notwithstanding the above, it may be possible when designing monitoring programmes to target reference sites (see section 5.4.4) or ‘hot spots’ of predicted climate change impact when adding new stations.

It is recommended to introduce the variable of uncertainty in the analysis and drafting of the water balances as a result of the impacts derived from climate change. **Rather than choosing a number on how much water will occur in future, start working with ranges of water volumes in relation to its probability**. This needs to lead to different criteria in the decision-making process for allocating resources for natural and human systems.

5.3.2 Monitoring of groundwater status

In the context of uncertainty, it is essential that monitoring is done to allow the type and scale of adaptation response to be adjusted according to the level of climate (and socio-economic) change experienced. Annex V of the WFD requires the quantity monitoring frequency and the network to be sufficient to enable a reliable assessment of the quantitative status, taking into account short and long-term variations in recharge and to assess the impact of abstractions and discharges.

Monitoring efforts should be also devoted to fast-changing and vulnerable groundwater environments. They can include karst regions, shallow groundwater bodies, strong surface water or glacier-dependent aquifer systems and coastal groundwater environments.

Long-term data sets

Specifically for groundwater, the recommended guiding principle for WFD monitoring is to ensure temporal continuity in both surface and groundwater monitoring sites, even if groundwater abstraction at the spring or well is abandoned (e.g. for quality reasons); this holds whenever a site is considered suitable for effective monitoring of climate change impacts. **It is recommended to set up an investigative monitoring programme (a climate change monitoring reference network as part of surveillance monitoring) for climate change and for monitoring climate change 'hot spots'** and to try to combine them as much as possible with the results from the operational monitoring programme. This includes reference sites in long-term monitoring programmes (e.g. focusing on areas without or with as low as possible direct human impact) to understand the extent and causes of natural variability and the impact of climate change. In order to detect climate change impacts early on, the monitoring frequency might need to be higher than the WFD minimum for surveillance monitoring. Otherwise, it can take a long time to gather robust time series.

It is recommended to **integrate relevant climate change parameters in surveillance monitoring programmes** to link climate change monitoring to existing long-term groundwater monitoring. Parameters should be defined and harmonised and a clear distinction between mandatory and optional ones should be made. Quantitative parameters (groundwater level, pressure head, spring discharge, transfer between groundwater bodies, abstraction rates, precipitation) as well as air and groundwater temperature are considered essential to establish the water balance and to understand changes. Hydrogeochemical, surface water, snow and glacier data or soil data can be relevant depending on the specific hydrogeological conditions.

In most cases, long-term groundwater level or spring flow data sets are rare, and most MSs appear to have completed research to identify existing records. It may be possible to reconstruct historic groundwater level or spring flow data sets using modelling or proxy approaches, with the appropriate caveats and characterisation of uncertainty clearly understood. Some MSs, such as Sweden, have implemented this approach. Climate change-relevant data is often held by water suppliers, communities or producers of hydraulic energy but is not accessible to water authorities. Hence, it is necessary to open currently inaccessible data sets.

Extreme events monitoring

Improving the monitoring of the impact of extreme events (e.g. intense precipitation and droughts) on groundwater-surface water interaction is important. Dedicated efforts should be directed towards the collection of monitoring data capturing the effects of such events, which are predicted to increase in frequency and intensity due to climate change. Additional monitoring carried out during droughts typically comprises more frequent logger downloads, citizen science initiatives to gather additional groundwater level data and low-flow spring flow measurements. Remotely observed information could potentially support these observations.

Monitoring changing seasonal variations

The lack of monitoring and assessments regarding seasonal groundwater level dynamics can be explained by the WFD's focus on annual averages. However, in many cases, climate change may lead to a shift in the months with the highest and lowest groundwater levels, an increase of amplitudes (higher and lower groundwater levels within a year), with associated ecosystem stress, while not causing a changing trend in annual average groundwater levels. Local requirements for increased frequency of monitoring or assessments of seasonal variations should be guided by the location of reference monitoring sites and groundwater bodies that are likely to exhibit such changes, based on the outputs of groundwater modelling work. In order to properly monitor drought in groundwater, the existing observation networks should be reviewed and modified accordingly.

Temperature sensitivity of groundwater recharge in simulation and observation

In a stationary climate, the amount of groundwater recharge depends on precipitation (mean temperature constant). With climate change, the precipitation sensitivity is additionally overlaid by the temperature or evaporation sensitivity (mean precipitation constant). To avoid misinterpretations of water balance simulations, it is essential to consider the temperature sensitivity of the applied water balance models. For this purpose, the different temperature sensitivities in space and time from observations (lysimeters, water balances of catchment areas) must also be analysed and considered. In Saxony (Germany), the temperature sensitivity of the groundwater recharge in the period 1961-2020 was in the range of 15 to 60 mm/a decrease per Kelvin temperature increase in approx. 100 catchment areas. Even if groundwater recharge is plausibly simulated in the initial state, if water balance models underestimate the temperature sensitivity, this leads to an overestimation of the simulated groundwater recharge from the climate projections and incorrect groundwater levels.

Remote observation

Several MSs are using remotely observed information, typically obtained from the Copernicus Programme. For example, in Ireland and Slovenia, satellite imagery is being used to monitor the flood extent of karst lakes (turloughs in Ireland and Poljes in Slovenia). In some cases, where the shoreline ground slope is a shallow gradient, it has been possible to use these observations to produce flood hydrographs of turloughs in Ireland. In other MSs research is underway to investigate whether remotely observed gravity data can be effectively used to estimate groundwater volumes within aquifers and for drought monitoring and potentially drought prediction. The responses indicate that remotely observed information is currently being used effectively to monitor at-surface phenomena related to groundwater quantity (groundwater flooding and groundwater irrigation) and that in future it may be possible to infer subsurface properties relating to groundwater quantity also. The potential cost savings and real-time provision of these data sources represent a significant opportunity to enhance groundwater monitoring across MSs, and most respondents indicated that they would be open to using such methods if and when they become available. Technical guidance on the use of remotely observed information or its incorporation into the CIS guidance document No. 7 on Monitoring under the WFD would support MSs in this activity.

Protected areas monitoring

It is essential to apply appropriate monitoring techniques for acquiring information to effectively protect drinking water protected areas (DWPAs). Environmental tracers have successfully been applied for the evaluation of travelling times and trend assessments under the WFD and GWD in some MSs and helped to frame future policies for the protection of drinking water well fields and supported the derivation of effective threshold values for chemical status assessment and trend analysis.

It is also recommended to implement an ecosystem approach in climate change monitoring by looking at both quantity and quality parameters in protected areas, to allow a sound assessment of climate change effects on groundwater and groundwater-dependent ecosystems. Current data in protected areas are typically too scarce and should be increased in time and space. The use of combined monitoring and modelling approaches should be promoted whenever possible.

31. Monitoring programmes within the WFD should provide an effective network for identifying and attributing changes in the water environment for validating risk of failure according to the WFD and assessing groundwater quantitative status, but in many MSs monitoring sites are under threat due to financial pressures. Water Directors should avoid, as far as possible, the decrease of monitoring and maintain stations with high-quality long-term records.
32. Maintain both surface and groundwater surveillance monitoring sites for a long time series. Set up an investigative high-resolution 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.
33. Do not systematically redesign monitoring programmes around climate change but, as part of general good practices, plan monitoring programmes carefully with a long-term perspective, assuring homogeneity and continuity in both the station network and the implemented methodologies. Do not abandon stations which already have a long-term consistent record.
34. Whenever possible, establish more intensive monitoring of vulnerable water bodies to better understand the pace and mechanisms of changes, and use these sites as sentinels of climate change. In all cases the minimum WFD monitoring frequency is applied, assess whether this is sufficient. In order to detect climate change impacts early, the monitoring frequency should be higher than the WFD minimum for surveillance monitoring.

5.4 Exemptions

Article 4 of the WFD requires MSs to achieve good surface water status and good groundwater status at the latest 15 years onwards from the entry date the WFD comes into force but provides the possibility for time-related and other exemptions. Paragraph 4 of Article 4 allows a MS to postpone the achievement of the objectives for two subsequent RBMP cycles, i.e. up to the end of 2027 (or beyond if the exception is justified based on natural conditions). Paragraph 5 of Article 4 allows a MS to target less stringent standards when the achievement of the full WFD 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 of natural cause or '*force majeure*' or the result of circumstances due to accidents, which are '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 or preventing the achievement of good status under certain strict conditions.

Whilst the use of exemptions is to some extent allowed under the WFD, this is subject to thorough justification in line with the WFD. Exemptions are not a general option to cope with the consequences of climate variability and climate change. Climate change can only be used as a justification for exemptions in limited circumstances where there is convincing and documented evidence and if all other conditions foreseen by the exemptions are met.

Art 4.4 and 4.5 WFD

Climate change cannot be used as a general justification for exemptions under Articles 4.4 and 4.5, at least in the short term, i.e. in the absence of appropriate evidence that the changes making it (technically) infeasible or disproportionately costly are the permanent result of documented climate change. It is necessary to include long-term analysis in assessments (see Chapter 2) and to base decisions on clear and substantial evidence, e.g. monitoring data (see section 6.5), and not to aim for less stringent objectives only based on limited modelled assumptions and exercises. 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 disproportionately costly or (technically) infeasible or that natural conditions do not allow timely improvement in the status of the water body. Where climate change is brought forward as the underlying reason for an exemption on the grounds of disproportionate cost or (technical) infeasibility, a complete and robust evidence-based analysis should be provided (e.g. use of more intensive monitoring of effects of measures in vulnerable water bodies). For instance, trend detection is insufficient to invoke a change of policy and process unless other elements are provided, such as the attribution of such a trend to anthropogenic climate change. Details on the process and difficulties associated with the attribution of changes to anthropogenic climate change are provided in the literature. The process for assessing the need for less stringent environmental objectives should therefore be closely linked to the economic analysis of measures. Guidance on including adaptation to climate change in economic analysis is given below in section 5.5.

If applying an exemption under Article 4(5) with climate change brought forward as the underlying reason, Member States still need to ensure the best status. Guidance document 20 (page 21) indicates that "a less stringent objective should represent the condition expected in the water body once all measures that are feasible and not disproportionately expensive have been taken".

As Article 4(5) states one of the conditions is that MSs ensure no further deterioration, Member States then also need to justify that the test on whether the environmental and socio-economic need of the activity preventing the achievement of good status could instead be provided by other means which are a significantly better environmental option not entailing disproportionate costs has been passed. Since the exemptions have to be interpreted narrowly, “other means” within the meaning of Article 4(5) have to be interpreted widely and include other types of measures and measures in other locations.

Art 4.6 WFD

There is evidence that extreme exceptional events, such as droughts, floods and surge tides will occur more frequently and will be more intense. The effects of these exceptional events which are exacerbated by climate change have been modelled with certain confidence and can be modelled for national and regional purposes. However, the application of Art 4.6 may be necessary several times in a row. Therefore, robust scientific evidence should determine on a case-by-case basis whether they can still be considered exceptional and/or difficult to foresee given their recurrence, as referred to in Article 4(6) of the WFD.

In the context of the application of Article 4(6), it is crucial to avoid any confusion between (unforeseeable) drought and (foreseeable) water scarcity. Water scarcity has a complex nature in which the increase in agricultural water demands and other socio-economic water uses, as well as inappropriate water management and planning (for example, over-allocation of water resources), usually play a major role. Art. 4.6 refers to natural events (extreme floods and prolonged droughts) that could not be reasonably expected and can also refer to an accident. Even though water scarcity may be exacerbated by an unforeseen drought, water scarcity is not caused by an extreme event such as an extraordinary drought. Therefore, where the main reason is water scarcity because of ineffective water management, even if causing important socioeconomic impacts, it could not be justified under Art. 4.6 and should be addressed within the general strategies to improve climate adaptation and water resilience. A clear distinction between drought and water scarcity is essential to avoid an inadequate application of Article 4.6.

Art 4.7 WFD

The implementation of specific adaptation and mitigation measures, for instance, infrastructure projects must generally support the achievements of the goals of the WFD. However, some measures might require exemptions according to Article 4(7) of the WFD, i.e. if they may cause deterioration of the status of affected water bodies or prevent them from achieving good status. Certain adaptation measures to climate change e.g. storage basins and structural flood measures can be counterproductive with respect to the WFD objectives in the sense that they may deteriorate the status of one or more affected water bodies (or even result in collateral damage of an ecosystem). Such measures or infrastructures, including water reservoirs, need to meet all the conditions set in Article 4.7 of the WFD on new modifications. The processes set out in Guidance No. 36 - Article 4(7) exemptions to the environmental objectives need to be followed as well as the preliminary rulings of ECJ (e.g. Case C-525/20, C-535/18C and C-461/13).

It should be noted that due to climate change additional or more stringent mitigation measures under Art 4.7 may be needed (e.g. measures to ensure appropriate e-flow). Once a project has been justified under Article 4(7) WFD, it may be necessary to re-classify the affected water body (e.g. as a heavily modified water body) or to apply a less stringent objective under Article 4(5) WFD, subject to complying with the criteria set out therein. There should be no further deterioration after the infrastructure project has been implemented.

Further, it is considered a good practice that any infrastructure project that falls under Art 4.7 is also subject to climate-proofing under step 2 (see section 10.2) (e.g. a hydropower plant is not developing its full potential due to predicted changes in the flow regime in the medium and long future).

35. Avoid using climate change as a general justification in the context of exemptions, in particular, to lower objectives under Article 4(5), as climate change is seldom the only reason for not achieving the objectives; all steps and conditions set out in the WFD for the application of exemptions shall be duly followed.
36. Decide, on the basis of robust scientific evidence and a case-by-case basis, whether a prolonged drought or the effects of an extreme flood allows for the application of WFD Article 4.6, i.e. whether these events can be considered sufficiently unforeseeable/unforeseen in order to be suitable to justify a temporary deterioration (where the climate change projections are solid enough, the changes are likely to result in permanent rather than temporary deterioration); climate change projections must be taken into account in this case-by-case approach to decide on foreseeability or not (prerequisite for applying Article 4(6)).
37. Apply WFD Article 4.7 to new adaptation or mitigation measures that modify the physical characteristics of water bodies (e.g. reservoirs, water abstractions, dykes) in order to accommodate climate change impacts but where these may potentially deteriorate the water status. Take all practicable steps to mitigate the adverse effects of these adaptation or mitigation measures and thereby consider that due to climate change, more efforts might become needed.

5.5 Economic analysis

Changing climatic conditions do not modify the requirements and the steps in the implementation of the economic analysis of the WFD; in fact, they render the economic analysis even more useful. To profit fully from this exercise, it is even more important than before to follow the sequential steps as suggested in the outline of WFD Annex III but now with the integration of potential additional pressures, impacts and constraints due to climate change.

WFD Annex III sets out that economic analysis should be carried out for two main issues in defining the RBMPs PoM, namely the recovery of costs of water services (taking into account long-term forecasts in supply and demand for water in the RBD) and for identifying the most cost-effective combinations of measures. In WATECO 2003 it is emphasised that "the economic analysis" in WFD covers more than just the economic analysis of water uses in Annex III to the Directive. Several of the results from the economic analysis of water use in Annex III to the directive are necessary inputs to the analysis of whether derogations to the environmental objectives are justified and in the analysis of heavily modified waters.

MSs have taken markedly different approaches to the economic analysis, in regards to ambition, detail and analytical robustness, since the challenges vary considerably across river basin districts in the EU and also because the available resources and expertise differ (proportionate analysis). Inevitably, the way climate change needs to be integrated into the economic analysis must, therefore, be different as well. However, it is strongly recommended that the required long-term forecasts in supply and demand for water incorporate scenarios for climate change as these forecasts constitute the basis for most of the economic analysis and thus also the investment planning. There is thus a strong link to the "pathways" approach from section 4.3, but even with a less elaborated assessment framework, the use of multiple scenarios is generally recognised as a best practice in taking account of deep uncertainty. In assessing combinations of measures to meet the WFD environmental objectives, options should be sought that can be shown to perform (and be cost-effective) under a wide range of scenarios for future climate change.

The justification to set an objective below good status (under WFD art 4(5)) for the current programming period should consider the impacts of climate change when assessing whether measures are infeasible or have a disproportionate cost. The latter requires a solid baseline mapping the consequences of climate change without the measures under scrutiny. For example, reducing water abstraction for irrigation might be seen as disproportionately costly because of its impacts on farmers and the local food and feed industry in the current programming period. However, these costs need to be seen in the proper context, namely set against the benefits of having water available for future agricultural activities in the long term (or other water-consuming activities if economically more worthwhile). The costs can only be deemed disproportionate when they would exceed the value of the measures with a wide margin (WATECO, 2003). On this basis, one needs to set the best possible status as a minimum objective without disproportionate costs. This approach is of vital importance in cases where water availability will change considerably over time and/or the water tariffs.

38. Explicitly consider climate change and the related uncertainty of its impacts when producing long-term forecasts of water supply and demand (including long-term trends and the adaptation strategies adopted in the water-demanding sectors).
39. Use multiple scenarios in the assessment of the effectiveness and costs of measures and the subsequent formulation of the most cost-effective package of measures, which would be best practice in many cases.

5.6 Measures for adaptation related to the WFD

5.6.1 Types of Measures and Principles for Selection

The WFD requires PoM composed by the MS, to achieve its environmental objectives. Improvements in the status of water bodies within the framework of the WFD will only succeed if measures, which account for these types of climate changes, are taken in a timely manner and are climate robust.

MSs have included several different measures in their RBMPs to achieve good status. They have been reported along 26 Key Types of Measures (KTMs) under WISE [21] and/or under the KTMs for Articles 17 and 19 of the EU Climate Law. Besides the KTM approach measures can broadly be further clustered along three types: grey, green and soft.

i. Grey measures refer to technological and engineering solutions to improve the adaptation of a territory, infrastructures and people.
ii. Green measures are based on ecosystem-based (or nature-based) approaches and make use of the multiple services provided by natural ecosystems to improve resilience and adaptation capacity. For example, the re-naturalisation of rivers contributes to flood prevention, climate adaptation and biodiversity conservation (See also Chapter 8). Their design and extent need to reflect new challenges related to climate change.
iii. Soft options include policy, legal, social, educational, management and financial measures that can alter human behaviour and styles of governance, contributing to improve adaptation capacity and increase awareness of climate change issues. In this context, soft options encompass both social and institutional measures as described by the IPCC (2014).

As good practice the measure selection should not only aim at achieving the objectives of the WFD but should also be taken to adapt (if relevant) to the pressures and impacts induced by climate change. In doing so, this should be done following Article 174 of the European Treaty which requires the precautionary principle and the principles that preventive action should be taken regarding environmental protection. Considering this fact there may be a need to consider whether additional measures are required to meet GES/GEP in changing climatic conditions. This is particularly not only the case where there are changes in physico-chemical conditions (e.g. to address invasive alien species that could not previously survive when water temperatures were lower).

Example 8: Priority and Reserved Areas for Groundwater Protection / Drinking Water Production.

Due to climate change, the already unfavourable water balance in some regions of Germany may further deteriorate. Altered precipitation and temperature conditions affect all processes in the water cycle, thus influencing the rate of groundwater replenishment and the quantity and quality of groundwater and surface water used for drinking water production. Increasing water scarcity and more frequent droughts can lead to regional conflicts over the use of primarily near-surface water resources.

State and regional planning can designate priority and reservation areas for drinking water and groundwater protection to secure water resources, moderate between different usage claims, and avoid or mitigate conflicts. Almost 80% of planning regions make use of this possibility. The high proportion of regions designating these areas makes it clear that spatial planning instruments are not only used in planning regions that are generally affected by water scarcity. Rather, the protection and securing of water resources also hold significant importance in water-rich areas, as their water supplies are partly utilised to support water-scarce regions. Nationwide, in 2017, approximately 39,000 square kilometres of land were designated as priority or reservation areas for drinking water and groundwater protection, which accounts for more than 10% of the country's area.

[21] See also: WFD Reporting Guidance 2022 Annex 8q

In general, a broad range of measures should be encouraged, and potential measures must not be removed just because they currently are not feasible or desirable (Siebentritt & Stafford Smith, 2016). Such options can become important at a later stage along the adaptation pathway.

Further, already in 2008, the Water Directors agreed that the PoM should be climate-proof. This assessment should analyse the impact changing climatic conditions may have on the effectiveness of WFD PoM or individual measures for achieving the WFD objectives. The aim should be to enhance the robustness of the PoM against changing climate conditions. Generally, only measures that are robust to climate change impacts and do not contribute to climate change should pass the climate check and should be considered in future RBMPs. However, this check is also economically relevant as investments for the long term (e.g. building new or upgrading urban wastewater plants) should be climate-robust.

The implementation of measures must be coordinated at the proper spatial scale, fit the specific local context and be compliant with international, national and subnational regulations and plans and stakeholder adaptation needs. Even though implemented at the local scale, measures often require coordination with higher levels of governance to ensure sustainable and harmonised spatial planning of the whole region.

Water managers preparing the PoMs also need to consider that other sectors will be introducing climate measures which may have implications for water management. Without this awareness, and where appropriate collaboration, there is an increased risk of maladaptation, also as some other sectors do not require climate proofing.

The WFD in Art. 11(3)(e) requires MSs to set up "controls over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register or registers of water abstractions and a requirement of prior authorisation for abstraction and impoundment. These controls shall be periodically reviewed and, where necessary, updated. MSs can be exempt from these controls, abstractions or impoundments which have no significant impact on water status." However, the last implementation report from the European Commission shows that **although almost all MSs have a permitting regime or register to control abstractions of groundwater and surface water, about half of all MSs reported that small abstractions are exempted from controls**.

5.6.2 Financing of adaptation measures

The costs of achieving the environmental objectives of the WFD and the FD are significant. In total, the capital investment costs of the measures planned in the 2nd RBMPs of the WFD reach at least EUR 142 billion and the total flood risk mitigation costs planned in the 1st FRMPs amount to at least EUR 14 billion. However, the overview of the costs of the planned measures is heterogeneous and incomplete (European Commission, 2021a). Therefore, the costs presented in this overview are likely to be an underestimate of the total costs incurred by the MS.

Financing and funding of measures is an important aspect of the planning process. Financial limitations are often cited as a barrier to initiating and implementing adaptation actions at the local level. However, adaptation funding and financing are available and can be combined from various sources – international, EU, national and local, both public and private. Good knowledge of available funding opportunities is important for overcoming this barrier. Mainstreaming adaptation into current planning processes and existing budgets is also an important option to consider. An overview of potential funding mechanisms can be found in Climate-ADAPT and the EU Mission Portal.

5.6.3 Cost recovery efforts

Article 9 of the WFD indicates that MSs must take account of the principle of the recovery of costs of water services, including financial, environmental and resource costs. These efforts have to be informed by the economic analysis as outlined in WFD Annex III, and to be in accordance with a proper application of the Polluter-Pays-Principle.

However, Art 9 does not require full cost recovery, not even for the financial costs, as authorities can set a lower recovery rate given the “social, environmental and economic effects of the recovery as well as the geographic and climatic conditions of the region or regions affected.” It is generally understood that the term “climatic conditions” does not provide a solid legal basis to exclude water service’ cost recovery efforts all the cost pressures coming from climate change.

They are also required to define water-pricing policies, which provide adequate incentives for users to use water resources efficiently and, in combination with the cost impacts of non-price measures, imply “adequate contributions” of key water user sectors (exceeding the customers of water services / their use of water linked to water services).

Climate change will cause significant changes in the quality and availability of water resources. The impacts are and will further manifest through changes and disruptions in local and global water cycles and have significant effects on sustainable water resource management and thus on water use throughout society and the economy. Although there are already visible climate change effects on these water cycles, there is still significant uncertainty around how these effects will occur at the regional and local level, as well as on the timing, magnitude and location of specific impacts (Kerres M. et al., 2020). In many regions water authorities (will) need to promote water use efficiency and stabilise and increase water supply (including through storage, water recycling and desalination) as well as improve flood protection and water level management (also in relation to protect and restore nature).

While the WFD gives considerable degrees of freedom to water authorities on setting the rate of cost recovery and the means to achieve it, the climate challenges necessitate a higher effort to attain the WFD environmental objectives and warrant sufficient, affordable water for all and for nature. It should spur water authorities everywhere to (re-)consider whether they make effective use of all available policy instruments, including those related to water services’ cost recovery (WFD art 9(1)). The long-term forecasts on water supply and demand (a mandatory element of the economic analysis, as stated in WFD Annex III) should serve as the basis for such policy (re-)assessments. Accounting for the “resource costs” of providing water services in times of water stress provides a pertinent example. However, other water uses as well as the PoM could be considered open for cost recovery efforts (often a good idea from an economic perspective), but the WFD does not say anything about this.

Hence, it can be expected that *ceteris paribus* the implementation costs of the RBMP's Programmes of Measures will increase, through larger investment needs and greater maintenance costs for providing water services as well as for other facilities directly tackling the climate impacts (on flood protection, regulating water level for energy generation or navigation purposes, and amenities such as to drain sealed surfaces and to protect vulnerable ecosystems). In general, it concerns measures to render water systems more robust to a broader range of potential hydrological conditions and change in pressures increased due to climate change as well as warranting minimal volume levels for essential water use such as in all cases drinking water supply. Widening the implementation of water tariffs and water-related charges enhances the efficiency of water (service) consumption and thus indirectly helps to avoid planning water facilities with a too large capacity and thus accommodating an unsustainable level of water consumption. Stable and transparent cost recovery arrangements facilitate unlocking untapped (private) sources of finance through innovating funding arrangements (including Payments for Ecosystem Services, Extended Producer Responsibility, or innovative fiscal policies, such as land value capture mechanisms) that can improve cost recovery for water services (OECD, 2022).

40. Take account of likely or possible future changes in climate when planning measures today in order to ensure the achievement of Good Ecological Status/Good Ecological Potential (precautionary approach).
41. Favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions (no regret measures).
42. Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including GHG emissions. The adaptation measures having cross-sectoral benefits mean adaptation of behaviour or (regulatory) standards used in production processes in the most related sectors (building, urban planning, infrastructure, agriculture, forestry, navigation).
43. Avoid the structural changes of natural water bodies as much as possible, as the best resilience to face Climate Change is provided by natural systems. Make use of NBS and avoid creating water dependency by water reservoirs and/or artificialisation as this will lead to more artificialisation and is counterproductive for the water ecosystem (maladaptation).
44. Enforce sustainable and cooperative water allocation within and across basins. Start adapting water management to the present and future impact of climate change as soon as possible in water permitting and enforcement for abstractions.
45. Make use of good practice examples, e.g. from existing research and implementation experience regarding adaptation strategies and measures.
46. Use the WFD consultation process (Art. 14) to bring in sector-specific knowledge and data from key stakeholders and in particular vulnerable groups.

6 FLOOD RISK MANAGEMENT AND CLIMATE ADAPTATION

The FD foresees a 6-yearly cycle to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods. In the EU, the three key steps of the flood risk management cycle are PFRA, FHRM, and FRMP.

Climate change should be taken into account throughout the flood risk management cycle. The FD states that the PFRA (Article 4, FD) shall, be based on available or readily derivable information such as records and studies on long-term developments, in particular the 'impact of climate change on the occurrence of floods' from the first cycle. Article 14.4 states that the 'likely impact of climate change on the occurrence of floods shall be taken into account in the reviews [of the PFRA and the FRMP]'.

This section of the Guidance will follow the three steps of the FD's risk management cycle to propose ways how climate change could be incorporated.

47. According to Art 14.4; start adapting flood risk management to likely climate change as soon as information is robust enough since full certainty will never be the case. Follow the guiding principles set out for the WFD.
48. Incorporate adequate resilient climate change scenarios in setting flood risk management objectives. In this process it will be necessary to communicate clearly the objective limits of possible public construction measures of flood protection.
49. Ensure coordination at the catchment level, (risk analysis, warming scenarios, potential measures, upstream/downstream impact of measures, warning), also respecting the Directive's coordination requirements at RBD/unit of management level.
50. Include adequate resilient climate change scenarios in ongoing initiatives and the planning processes.
51. Favour options that are robust to the uncertainty in climate projections:
    a. First focus on life protection of people in areas at risk of flash floods or storm surges.
    b. Focus on pollution risk in flood-prone hazard zones.
    c. Focus on non-structural measures (e.g. wetland restoration, giving rivers more space) when possible.
    d. Focus on 'no-regret' and 'win-win' measures and use synergies with other objectives, e.g. reducing the effects of drought.
52. Favour prevention through the catchment approach, with special attention to the restoration of and/or the protection of water retention in the capillaries of the water system, to the infiltration in the soil feeding groundwater bodies/aquifers, to various wetlands, including the flood plains along all streams and rivers.
53. 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).
    a. Include long-term climate change scenarios in land-use planning.
    b. Develop robust cost-benefit methods which enable considering longer-term costs and benefits in view of climate change, including ecosystem services.
    c. Use economic incentives (e.g. eco scheme payments, insurance, taxes) to influence sustainable climate adaptation in land use.
54. Assess other climate change adaptation (and even mitigation) measures by their impact on the flood risk:
    a. Hydropower and flow regulation.
    b. NBS solutions.
    c. Link with water scarcity.
55. Pay special attention to the requirements of WFD Article 4.7 when developing flood protection measures.
56. Determine based on robust scientific evidence and on a case-by-case basis whether an extreme flood allows for the application of WFD Article 4.6.

57. Pay special attention to the vulnerability of protected areas in view of changed flood patterns.

6.1 Preliminary flood risk assessment (PFRA)

Article 4.2 of the FD 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’[22].

Using Climate models

It is important to understand the potential range of change in flood hazard and risk related to the effect of different climate change scenarios. In order to facilitate global comparison purposes, it is recommended to use official scenarios, like the IPCC AR 6 scenarios, as well as the outcomes of national research and assessments. The IPCC AR6 considers five possible future scenarios (Shared Socioeconomic Pathways (SSPs))[23]. The Coordinated Regional Climate Downscaling Experiment (CORDEX) has also produced climate data at a higher resolution. All these climate projections or data are available from Copernicus.

However, it can be challenging for MSs, water managers and flood risk managers to use the raw outputs of climate change models, as there was a lack of guidance identified on how to incorporate these effects in flood frequency estimations (European Commission, 2021b). Flood frequency estimations are indeed still mostly undertaken by using methods based on a fundamental assumption of stationary historical records for flood flows and/or precipitation (Castellarin, et al., 2012), while natural climate variability and cycles are often not addressed as the estimation of flood frequencies in a non-stationary climate remains scientifically challenging.

Therefore, it is recommended to liaise with the national or EU meteorological services[24] in order to identify climate projections that should be used for the assessment[25]. For consistency, the same range of projections should be used at a RBD level, and national level but also at a local level to set a basis for the development of hydrological models. By considering more than one scenario of future climate-related hazard projections, uncertainties can be better illustrated.

[22] In the context of the above-mentioned extension of time spans of usable records into history thorough analysis of available information on floods should be also considered, as it can be helpful for both the accuracy improvement of flood frequencies and for better understanding the impact of climate change.

[23] The IPCC AR6 considers five Shared Socioeconomic Pathways (SSPs), which explore possible futures, based on integrated assessment models (IAMs) of socioeconomic trends and associated climate, modelled by the World Climate Research Programme in CMIP5 and CMIP6. The IPCC previously only considered Representative Concentration Pathways (RCPs) of greenhouse gas emissions and associated climate, modelled by CMIP5.

[24] Go to Climate-ADAPT and then select your country from the dropdown list to go directly to the country's page. Then click on a tab on the right called “Contact”. The relevant contact details of the services will be shown if your country has reported them.

[25] Be aware that the properties of some physical processes that occur at a finer resolution than a model’s outputs are averaged. As such, you may be attracted to use downscaled model outputs but bear in mind that, in other ways, downscaling increases rather than decreases uncertainties.

For planning purposes, it might be beneficial or good practice to consider future land use and uncertainties. These can have major impacts on flood flows, a possible direct effect on the impact of hydrological extremes (e.g. increased paved surfaces create higher flood risk peaks) but also on outlining new hazard areas (e.g. new building areas that might be affected by extreme floods). Although it can be difficult to distinguish between the effects of land use change and climate change on future floods, it may be necessary for MS to evaluate these drivers individually and consider their combined impacts on flood risk.

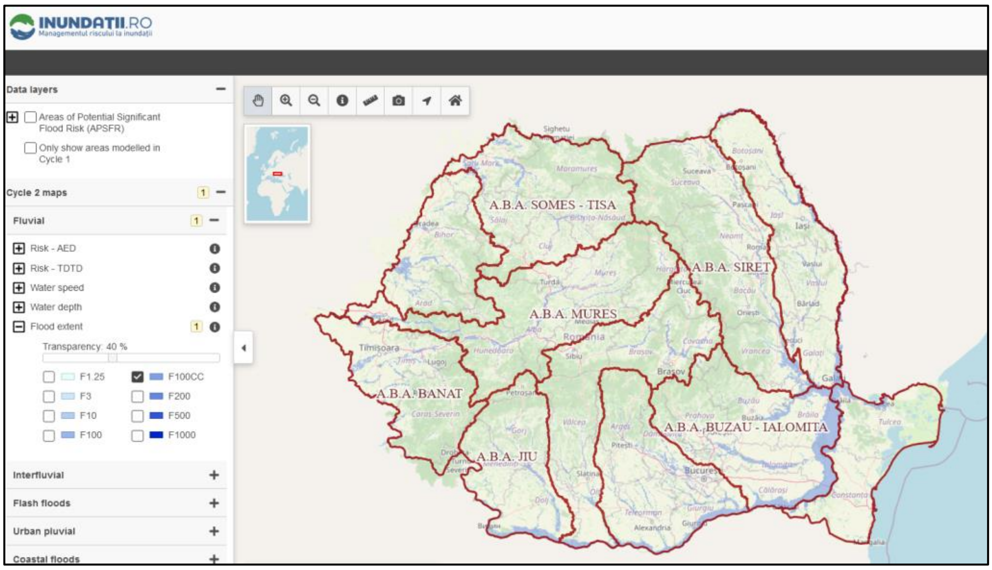
58. Understand and anticipate as far as possible increased exposure, vulnerability and (flash)flood risk due to climate change, for establishing areas of potential significant flood risk.
59. When delineating various flood scenarios, take into account the impact of climate change over a time span of at least 50, and preferably 100 years.
60. While not a requirement of the FD, use the 6-year review of flood maps if data is robust enough to incorporate climate change information explicitly covering an adequate time horizon of 50 and 100 years for different frequencies of occurrence.
61. Recognise the combined impacts of both anthropogenic changes (e.g., land use and hydro-morphological alterations) and climate change on future flood risks, acknowledging uncertainties, their interplay and assessing their effects on flood risk.
62. Stimulate collaboration between (inter-)national research institutes and climate services to further develop local-scale climate information (especially in countries with currently limited capacity).
63. Improve the collection and sharing of flood losses with high spatial and sectoral detail and use this information in the construction of their flood loss models.
64. Consider intensifying the cooperation between insurance companies, flood managers and stakeholders.

6.2 Flood hazard and risk maps (FHRM)

MSs are not mandated to show the influence of climate change on floods in the maps. However, showing the changes in the flood extent of the different climate scenarios would support awareness raising significantly for areas identified in consecutive cycles.

Example 9: FHRM in Romania

Romania provides in its FHRM besides different scenarios one dedicated to climate change (F100 cc). To estimate the impact of climate change on maximum river discharge a scenario with 0.1% flooding probability was used. Romania compared the projections for 2021-2050 with the reference period 1970-2000. Three classes of changes were considered: (1) regions where maximum discharge will not change (stationary), (2) regions with a moderate increase of maximum discharge (10%) and (3) regions with a significant increase of discharge (20%).



Even if some progress has been made with regard to uncertainties in climate projections and the methods to consider them in the context of the FD, further development of analytical methods to assess flood hazards in a changing climate and cartographic methods are still important, as they may help to visualise probabilities and uncertainty in flood-mapping products. Further development of mapping methodologies, technologies and tools would also help combine the differences in projections. This would help in terms of knowing where flood patterns are expected to change with climate change, regarding fluvial, pluvial floods (urban/rural), coastal floods, extreme river floods, flash floods, groundwater floods, ice jams and frazil ice floods, etc.

6.3 Flood risk management plans

6.3.1 Flood risk management objectives

Article 7 of the FD requires MSs to establish appropriate objectives, ‘focusing on the reduction of potential adverse consequences of flooding and, if considered appropriately, on non-structural initiatives and/or the reduction of the likelihood of flooding’. The FRMP shall include measures to achieve these objectives. All EU countries according to their conditions and specific geographical region, are thus required to take adequate and coordinated measures to reduce flood risk at all governance levels, and ‘focusing on prevention, protection, preparedness, including flood forecasts and early warning systems and take into account the characteristics of the particular river basin or sub-basin’. The likely impact of climate change on floods shall also be considered in the review of the plans (Article 14 (4)).

6.3.2 Measures for adaptation related to the FD

The measure selection should consider long-term perspectives, favouring prevention through the catchment or sub-catchment approach, and options that are robust to the uncertainty of climate projections (focusing on communities, critical infrastructure and pollution risk in flood-prone zones, non-structural measures, ‘no regret’ and ‘win-win’ measures as well as on mixes of measures).

Further when establishing measures, according to Article 9 of the FD, FRMP should take into account and be in coordination with the general and environmental objectives of the WFD (reach ‘good status’ in water bodies) to improve the synergies between the two directives, as well as the objectives of the European Green Deal, the EU Climate Law and the EU energy policy (e.g. the Governance of the Energy Union and Climate Action Regulation). And vice versa the measures in the WFD programmes of measure shall take into account all the information that is provided from the FD 3 steps. It is also important when defining and implementing the measures to be put in place to counter flood risks, and in particular grey infrastructure[26], to consider the environmental consequences and to prioritise where possible sustainable and no-regret solutions with a view not only to the short-term but also to the medium and long term. The public safety aspects of flood risk management also need to be further emphasised, in particular regarding civil protection measures and crisis management. Considering the multiple benefits, the restoration of wetlands and the improvement of the resilience of ecosystems is key to climate change adaptation (see also Chapter 8).

In case of extreme and sudden weather events, causing the risk of flooding, cross-border communication needs to be instantly set up and actions, especially in the upstream country, need to be synchronised (agreed) to minimise risks and potential damage.

In addition to these aspects, adopting the following approaches is recommended when it comes to developing FRM measures.

6.3.3 Adopting an integrated approach

Comprehensive policy frameworks, such as Integrated Flood Management, are based on risk management principles that explicitly recognise the residual risks on the floodplains while taking a comprehensive perspective of floods, river health, as well as benefits and risks of floodplain use. The development of a holistic integrated FRM is a key issue for the adaptation to climate change, as it draws a link between economic and social development, environmental protection and strengthens the resilience of nature and society to extreme weather events. There are several principles for the development of integrated flood management plans:

i. Managing the water cycle as a whole, improving stakeholder participation.
ii. Adopting a mix of best measures (including nature-based and ecosystem-orientated solutions) with a multi-disciplinary approach.
iii. Better integrating water and land management[27].
iv. Developing risk-informed decision-making and preventive measures[28].

[26] Grey infrastructure can damage biophysical and hydrological processes, seal soils and buried streams. Compared to grey physical infrastructure, natural infrastructure is often more flexible, cost-effective and can provide multiple societal and environmental benefits simultaneously (McVittie et al., 2018; UN Water, 2018; IPBES, 2019).

[27] See also the EU Soil Strategy regarding soil protection and prevention of flash floods.

[28] MSs and local authorities, as well as flood and water managers, are strongly invited to consult the Guidance Document by the WMO in 2017 and the EEA report on NBS (EEA, 2021a) for detailed information.

v. Harmonising flood prevention measures, including those included in FRMP, with the water scarcity and drought prevention measures included in RBMPs.

In this respect, the EEA (2021a), offers solutions that should be implemented by MSs and local authorities, in line with the Integrated Flood Management principles. It develops case studies of the effectiveness of nature-based responses to (flash) floods in Annex 4 (A4.1 and A4.2). Chapter 9 of this guidance document is also dedicated to nature-based solutions.

6.3.4 Awareness raising, early warning and preparedness

Sensitising the EU's population to climate change and risks, especially floods, is still a work in progress as the assessment of the 2nd FRMPs shows. All MSs and stakeholders must support the encouragement to raise awareness and the necessity of self-protective measures for citizens about an increasing risk of floods due to climate change, through available FHRM for the public. Public digital flood viewers which are applied in most MSs are a useful approach towards awareness rising. Furthermore, education and press campaigns on different scales that are easy to follow should promote the necessity of adapting and building suitable protection against floods. Local (planning) authorities, as well as private actors, should be involved to raise acceptance of measures and combine them with other climate adaptation mechanisms possible.

In October 2023, the Commission published a new flood risk areas viewer to raise awareness about potential significant flood risks. The viewer is provided with the support of the EEA and reflects work carried out by the MSs under the FD. Users can zoom in to see which areas of potentially significant flood risk have been identified by each MS. The MSs themselves define what constitutes a significant flood risk. By clicking on the map, users can display relevant information and links to the MS' PFRA, FHRM and FRMP.

It is important to draw the link between flood risks and other hazards, advocating for coordinated emergency measures to reduce the overall risk. Climate change is leading to an increase in the number and intensity of hydrometeorological hazards, which makes the improvement of civil protection necessary. Particular attention should be drawn to warning systems, institutional and material preparedness at the local, EU and MS scales (in the case of simultaneous and large-scale events).

6.3.5 Improving the process of integrating climate change science into flood risk management practice

To facilitate research related to FRM and cooperation between scientists, flood risk managers and policymakers, specific platforms at national and/or regional (i.e. pan-European or large transboundary river basin) scales should be reinforced (European Commission, 2021b).

7 DROUGHT MANAGEMENT AND CLIMATE ADAPTATION

Although temporary droughts are a characteristic of certain climate zones such as the Mediterranean, droughts and (subsequent) water scarcity can significantly affect the environment, economy and society.

Due to climate change, the risk of long periods with no precipitation in combination with higher evaporation due to temperature rise and heat waves will increase in large areas of Europe. The increased frequency, length and intensity of droughts requires dedicated efforts and responses in terms of preparedness, sustainable water management and reduction of water consumption.

7.1 River basin management plans and drought management plans as tools for addressing water scarcity and droughts

According to the WFD, RBMPs are an appropriate framework to deal with unsustainable water use leading to water scarcity. They shall include explicit references to drivers and pressures of water scarcity, as well as corresponding status assessment references (in particular to the hydromorphological status of surface water bodies and the quantitative status of groundwater bodies). RBMPs shall also include measures to reduce significant abstraction pressures, incentivise efficient use via water pricing, manage water demand, promote efficiency, reuse, desalination, manage aquifer recharge, education, etc. for achieving the WFD environmental objectives. Most measures – for which the Commission establishes a hierarchy of action – can also be considered as a contribution to enhanced preparedness and resilience towards drought events.

RBMPs can also contribute to mitigating the effects of droughts. The European Commission recommends establishing specific DMPs (European Commission, 2019; European Commission, 2021c). The European Council recognised their usefulness (European Commission, 2010) and called for the improvement of water scarcity and drought management strategies. However, DMPs can have the format of a chapter in the RBMP or stand-alone documents or be integrated into other relevant strategies (e.g. adaption strategy) adopted by MSs to manage water scarcity and drought events (Schmidt, et al., 2023). Independent from the format, three key elements should be included in these strategies:

i. Indicators and thresholds establish the onset, ending, and severity levels of exceptional circumstances (drought).
ii. Measures are to be taken in each drought phase to prevent deterioration of water status and to mitigate negative effects.
iii. An organisational framework to deal with drought and subsequent revision and updating of the existing DMPs.

Indicators shall ideally also build on the drought indicators set by the European Drought Observatory, as this can ease transboundary and pan-European management of droughts; as well as on the Water Exploitation Plus index compiled by Member States and the EEA for water scarcity. Monitoring of drought impacts is encouraged to foster further preparedness, as well as to take the appropriate relief and response measures.

Several drought management approaches are currently in place – some define the priorities for actions, including water resource management (to ensure adequate distribution of resources, e.g. water supply), ecosystem conservation strategies (aiming for the protection of ecosystems, habitats or species, and ecosystem services), risk management (focusing on the stepwise application of preparedness, mitigation, relief and restoration measures during a drought event, and/or addressing the hazard, exposure and vulnerability), climate adaptation (with droughts as one component of such strategies, also possibly addressing heat waves and wildfires), and sector-focused management.

Example 10: Drinking Water Security Plan

In July 202,3 the Austrian Ministry published a Drinking Water Security Plan, which was developed in coordination with the 9 federal states to develop a programmes to ensure future drinking water security. It contains a guide in dealing with drinking-water shortage and a 5-point, long-term programmes including the improvement of the data basis and forecasts for planning and preparations for measures, the promotion of research for efficient water use, awareness-raising activities for the careful use of drinking water, secure financing of the drinking water supply in the long term, and a regular evaluation of drinking water supply concepts.

Example 11: Spain's Drought Management Plan

Like many other European MSs, Spain has traditionally managed droughts as a crisis only by applying emergency procedures and urgent measures (through the adoption of Emergency Drought Orders or Decrees). However, that approach failed to achieve the most sustainable and cost-efficient solutions in the long-term. After the devastating environmental, social, and economic consequences of the 1991–1995 drought period, a paradigm shift towards a drought risk-reduction management approach in Spain was necessary. Since 2001, Spain's government has established hydrological indicators to help River Basin Authorities identify a looming drought situation early enough.

Based on guidance documents of the Spanish government, RBA adopted DMPs for the first time in 2007. Since then, these DMPs have been updated in synch with the RBMPs, every six years. Like the RBMPs, the DMPs are also subject to public consultation, allowing stakeholders from water-consuming sectors to provide inputs and include principles and measures to address drought risks, including the possibility of a reduction to minimum ecological flows during severe droughts.

Spain's DMPs differentiate drought events from water scarcity episodes in terms of root causes, consequences, and required actions to deal with each scenario. Temporary water scarcity, because of droughts, is dealt with in DMPs. Permanent water scarcity, not due to droughts, but because of inappropriate water management (which of course can be exacerbated due to droughts) is to be addressed in the RBMPs. In addition, the Spanish legislative framework states that local authorities in water supply systems with more than 20.000 inhabitants must establish and implement emergency plans in case of droughts (Hervás-Gámez & Delgado-Ramos, 2019).

The state of the art of drought management planning presupposes forecast models in addition to only using historical probabilistic precipitation, flows, reservoir storage and piezometric level information (Hervás-Gámez & Delgado-Ramos, 2019). With the increasing availability of data on droughts at regional and national levels, and the modelling of climate impacts in national and regional climate adaptation strategies, the relevant authorities shall share a common framework in terms of data, impact modelling and mitigation scenarios across different sectors. Water managers shall increasingly use predictive models to anticipate and evaluate future impacts of a drought.

Specific drought management relief and response measures are implemented by the MSs (Schmidt, et al., 2023). Most of them are operational demand and supply measures, followed by economic impact compensation measures, increased control and enforcement measures, operational measures for the environment, and organisational measures. Only a few MSs foresee and implement follow-up and recovery measures after a drought, which makes it more difficult to improve over time.

Water allocation priorities under droughts are in place for more than half of the MSs (Rouillard & Schmidt, 2023). Priority water allocation schema shall be based on, among other factors, recent water accounts for the RBD (European Commission, 2015), which improves the accountability and transparency of the administrative action. The level of complexity and detail can be related to the severity of the water scarcity, including possible water use restrictions affecting more than the water use sectors. The ranking criteria often reflect the societal relevance, economic importance, and ecosystem values related to water, but do not use criteria of sustainability, efficiency and/or equity. It is strongly recommended that the ranking system includes the implied price differential between sectors caused by the allocation quantity decisions as a key factor.

65. Use the WFD to achieve climate change adaptation preparedness in areas of water scarcity and to reduce the impacts of droughts, e.g. achieving good quantitative groundwater status supports a more climate-resilient water system.
66. In areas under relevant drought risk, adopt appropriate strategies aligned with the principles of DMPs (previously identified indicators and thresholds, measures and governance frameworks), to handle drought situations.
67. Ensure the consistency of sector-specific strategies with plans and measures for drought preparedness and emergency management.
68. Ease transboundary and pan-European management of droughts by using a common set of indicators, ideally based on the drought indicator set of the European Drought Observatory.

7.2 Monitoring and detecting climate change effects on droughts and water scarcity

Many EU MSs do have monitoring systems in place, addressing climate change, water and droughts (Rouillard & Schmidt, 2023), from national to local scale. In addition, the European Drought Observatory (EDO) was initiated by the European Commission's Joint Research Centre (JRC) in 2008 and, since 2018, has been part of the Copernicus Emergency Management Service (CEMS), providing up-to-date information on the evolution, occurrence and forecasting of droughts in Europe. EDO publishes maps of updated indicators and follow-up reports on the most severe episodes. CEMS is part of the Copernicus programme services and supports all actors involved in managing natural or manmade disasters by providing geospatial data and images for informed decision-making, based on an agreed indicator set. Furthermore, the EEA provides updated information about the evolution of water consumption in European river basins. This information is based on the Water Exploitation Plus Indicator, based on information from the MSs. In line with the adoption of the new EU Strategy on Adaptation to Climate Change from 2021, the European Commission (DG Environment and the JRC) launched the European Drought Observatory for the Resilience and Adaptation project (EDORA), aiming to improve drought resilience and adaptation throughout the EU. The JRC published a Drought Risk Atlas which includes methodologies of the impact chains and quantitative risk estimations developed and can be transferred to other scales (e.g. MS, river basins). This allows the use of more detailed information and high-quality data and enables targeting specific systems and impacts that are particularly relevant for the respective context (Rossi, et al., 2023).

69. Diagnose the causes that have led to droughts or water scarcity in the past and/or may lead to it in the future.
70. Monitor water abstraction and consumption closely and create forecasts based on improved knowledge of demands and trends. Distinguish climate change signals from natural variability and other human impacts with sufficiently long monitoring series.
71. Use detailed, up-to-date information, maps and early warning systems available from European, national, regional and local levels, including EDO, CEMS, and EEA, ensuring timely and informed decision-making in response to drought events.

7.3 Adaptation measures related to water scarcity & droughts

Adaptation measures should be based on proper risk assessments under current and future climate conditions and should follow a water-smart economy and society approach. This means that all available water resources, including surface-, ground-, rain-, waste-, and process water, are managed in a way to avoid water scarcity and pollution. Such actions could demonstrate resource-efficient solutions derived from the systemic exploitation of symbiotic inter-linkages between wastewater treatment in industries and water utilities.

The optimal combination of measures should be based on a cost-effectiveness analysis considering the expected socioeconomic and climate change scenarios. In addition to the direct (water volumetric) benefits – which can be primarily measured in terms of improving the water balance – multiple other considerations must be factored in, such as local natural and social conditions, the provision of other co-benefits and/or the avoidance of maladaptation and negative externalities, and the persistent effect of achieved efficiency improvements on water consumption.

For example, negative externalities might occur when water reuse is practised as a measure to mitigate the impacts of water scarcity. However, river bodies receiving a high share of wastewater effluent might be adversely impacted when the effluent is reused instead of being discharged into the stream. Thus, environmental flows shall be considered when assessing water reuse as an option.

Example 12: Digitalisation of Spain's water cycle

The Government of Spain has allocated 200 million € of the Recovery and Resilience Facility to digitalise the water cycle in irrigation water user associations through a competitive process. The programme aims at completing the identification of water uses for irrigation, promoting transparency, improving efficiency, rationalising the use of agrochemicals to improve water quality and optimising the use of energy. Successful applications will use digitalisation to build information systems used for local irrigation management, real-time measures and report water abstractions and allocations, monitor the quality of irrigation return flows, supervise soil water and fertilizer leaching in irrigated areas, and introduce renewable energy for water pumping.

Example 13: ADAPT2CLIMA Decision Support Tool

The ADAPT2CLIMA Decision Support Tool aims to enhance the understanding of climate change and its impacts on agriculture in order to support farmers, policymakers and other relevant stakeholders (agronomists, agribusiness industry, etc.) in adaptation planning. The tool is currently applied in Cyprus, Crete (Greece) and Sicily (Italy) to visualise the crop performance water availability in relation to climate change via maps and graphs using the tool. Moreover, the tool may be applied to explore the available adaptation options for addressing climate change impacts and their efficiency in increasing resilience in agriculture.

72. Limit future water abstraction and consumption to use-relevant projected availability under relevant climate change scenarios.
73. Follow an integrated approach based on a combination of measures.
74. Interconnect urban water supply systems.
75. Engage stakeholders to produce decisive measures to tackle water scarcity.
76. Assess other climate change adaptation and mitigation measures according to their impact on water scarcity and drought risks to avoid maladaptation and promote synergies.
77. Have authorisation regimes and regularly updated registers for all types of water abstractions including small ones. Monitor the cumulative impacts of several abstractions and their impacts on other environmental legislations including the Nature Directives.[29]
78. Ensure that any new impoundments such as water reservoirs are conditional to an Article 4.7 test under the WFD, including a proper justification. No artificial impoundments or reservoirs (other than natural water retention measures) should be built in or impact protected rivers, wetlands and habitats, including Ramsar sites, Natura 2000 sites, ecological corridors, and other types of protected areas recognised at local, national or international levels.
79. Develop water use efficiency, saving and consumption targets for all water users, at the sub-basin or basin level.

7.4 Priority Water Allocation under water scarcity conditions

Water allocation mechanisms[30] can be defined as the combination of institutions which enable water users and water uses to take or to receive water for beneficial use according to a recognised system of rights and priorities. These mechanisms define who is allowed to access water, how much may be taken and when, how it must be returned, and the conditions attached to the use of the water. In addition, allocations must account for the range of uses needing specific flows or levels of water in rivers and lakes such as the environment, navigation,

[29] When granting authorisations for water abstraction, Member State authorities should systematically take into account the status of the water body concerned, and the foreseeable trends in water availability. This should include the expected effects and uncertainties resulting from climate change, as well as the direct and indirect impacts of the abstraction on the water body (including on the ecological status of the surface water body, i.e. fish populations, and the quantitative status of the groundwater body). Water planning needs to include a climate change uncertainty analysis, in order to define risk scenarios that can help set the maximum annual (or monthly) quantity that may be abstracted.

[30] The CIS Ad Hoc Task Group Water Scarcity & Droughts discussed the contribution of water allocation mechanisms to the WFD and the role of water allocation mechanisms for mitigating climate change impacts during the 2020-24 mandate based on the report "Implementation of water allocation in the EU", available for download **here**. From this work, a number of general principles emerged that can be seen as good practice to adapt water allocation regimes to climate change. These recommendations are – like CIS Guidance in general – non-binding for EU Member States.

recreational users including anglers, water-based tourism and fisheries. **Allocations can be issued in different forms**: permits, time-limited allowances or long-term or permanent entitlements – or a combination of those when for instance permits are modulated by annual or seasonal restrictions.[31]

Water allocation regimes can pursue several competing objectives: economic efficiency, environmental sustainability and social equity.

Economic efficiency is concerned with allocative efficiency, that is allocating water to the highest economic value uses. Environmental sustainability aims at the hydrological integrity of the system. In the European Union, these are determined by the legally binding objectives of Article 4 of the WFD for achieving a good status of surface and groundwater bodies. Social equity objectives finally strive to achieve some level of social justice between user groups. For instance, access to drinking water is considered to be a human right.

Obviously, depending on each EU Member State's policies, the emphasis of one aspect above another aspect will differ. However, to some extent, all three objectives can be found in water allocation regimes, as all MSs strive to somehow balance economic, environmental and social needs. How this balance is struck will strongly be influenced by historical circumstances that have shaped existing allocation arrangements, the relative weight given to certain policy objectives over others, and the prevailing political orientation (OECD, 2022a).

In the European Union, the WFD establishes implicitly that the water balance is the foundation for determining sustainable abstraction levels given available renewable freshwater resources based on requirements for *ecological flows*. Only once sustainable abstraction levels are known, by identifying ecological flows, water managers can identify a surplus that is subject to allocations for different use cases. **Establishing ecological flows is therefore a starting point for WFD compatible sustainable water allocation regimes.**

Under the WFD, MSs are required to establish controls on the use, abstraction and discharge of water (Art. 11.3) in the form of registers and prior authorisation through permitting regimes. Permits are a key tool to implement WFD-compliant allocations. While registration, metering and/or licensing/permitting of water abstractions are carried out by nearly all MSs, most of them have **not yet sufficiently taken into account potential climate change risks within their abstraction regulation processes**. Specifically, which regulatory actions are required when drought and severe water stress occur, and which ones to adequately anticipate such events. This represents a clear opportunity to achieve adaptation goals and improve resilience. To deal with water scarcity, several affected MSs have defined priorities for water allocation under drought or water scarcity conditions. The widespread occurrence of severe and prolonged droughts in Europe in the last years has given prominence to the issue.

These priorities decide which users can use the resource when supplies are not sufficient to meet all demands. However, water scarcity occurs whenever the demand exceeds the available resources, be it through changes in physical availability or demand-side stress. Consequently,

[31] See the report "Implementation of water allocation in the EU", page 9, available for download **here**.

and under an uncertain climate future, regions that have so far been spared by droughts can benefit from proactively thinking about water allocation priorities. Such allocation mechanisms can support effective management to maintain ecosystem health when imbalances between demand and supply or droughts occur and provide clarity for affected stakeholders.

How to set priorities, however, is a complex task, that depends on regional hydrological conditions and needs as well as the specific legal and regulatory context. There is no one-size-fits-all hierarchy, and water managers face questions of sustainability, social equity, flexibility, and feasibility, among others. Although not a requirement under the WFD, this section shall provide preliminary guidance on how to define water allocation priorities to be prepared for scarcity conditions and grant planning security for stakeholders.

Example 14: Priority water allocation

16 MSs currently have priority water allocations during water scarcity. Many are established on a national level, while some MSs grant authority within the national priorities to regional management or RBD levels, embracing regional contexts (Schmidt, et al., 2023).

Example 15: Overarching principles that steer prioritisation in Flanders

In 2022, the Flemish Government defined in discussion with stakeholders several overarching principles that steer prioritisation, as well as binding boundary conditions that place the highest absolute priority on certain needs (in this case dykes, sensitive nature and navigation). Subsequently, Flemish sub-areas specify their specific prioritisation under consideration of the real-time hydrological conditions, and the defined principles and boundary conditions.

While no order of prioritisation applies to every context, some common principles from current practice and important criteria are collected to guide the allocation process:

Define the Allocable Pool, accounting for ecological flows

Central in allocating water, is knowing the allocable pool of the resource throughout the seasons and under changing hydrological conditions, based on updated water balances. The allocable pool is the flow or volume of water available for use in the basin, be it uses that extract and consume water such as drinking water, agriculture and industry, or uses dependent on specific water levels in rivers, lakes and groundwater, such as navigation, hydropower and water tourism. The allocable pool is defined based on hydrological conditions alone (as well as time period). Depending on water demand and the scope of the prioritised water uses in the basin, the “allocable pool” may be above the current demand or may pose a limit to the current demand.

Securing a hydrological regime that maintains ecosystem functioning is a requirement to achieve the environmental objectives specified in Article 4 and Annex V1.2.1 of the WFD. For surface waters, such a hydrological regime shall be captured by the ecological flows, which define water quantities as well as the timing, velocity, and duration of flows or water levels needed to achieve good status. For groundwater bodies, good quantitative status shall be achieved, also considering the groundwater dependencies of ecosystems. This principle should also be kept under drought conditions, whilst Art.4(6) exemptions might be applied e.g. to ensure drinking water supply. Thus, the allocable pool of water only comprises the surplus (available water resources minus ecological flows). Information on how to determine, ensure and update ecological flows can be found in Guidance ecological flows (a new one to come in October 2024).

Safeguard social equity and economic policy considerations

Existing allocations already place drinking water and critical infrastructure high on the list, in line with Article 16 of the Drinking Water Directive. The former is of course related to the notion of affordable access to drinking water as a human right. Which water use is a priority after that should depend on national, regional or local considerations on social equity and sustainability, as well as some economic criteria. Such priorities shall consider all water uses, not only those who abstract and/or consume water.

A prominent economic factor to consider is the water users' relative need to have assured access to a given stable water supply. Economic agents would be willing to pay to obtain such "allocation rights" but there is currently too little experience with market mechanisms to provide guidance. Many allocation mechanisms try and take account of wider economic stability considerations, trying to prioritise based on avoided jobs and value added. Yet, a rigorous orientation of priority setting based on indicators reflecting economic benefit or jobs per water volume unit may give too little weight to efficiency improvement potential (see below) and the interrelatedness of sectors. In addition, a stable water allocation may degrade into a system of established water rights or set on the basis of political clout.

Target Efficiency

In currently existing allocation mechanisms, efficiency is not discussed. How efficiently water is used, however, affects the amount that can be allocated during scarcity. The principle 'water efficiency first', with its origins in the 2012 Water Blueprint, can thus be useful to consider. Water allocation priority could, for example, always come with the requirement to achieve established water leakage levels (e.g. in accordance with Art. 4(3) DWD) to reduce water abstraction for a given consumption level. Further, the WFD under Art 9(1) requires that water-pricing policies, alone or in combination with other policy instruments, provide adequate incentives to use water resources efficiently.

Maintain flexibility

Important in the effectiveness of the allocation mechanism is the level at which certain priorities are defined. As a rule, the higher the number of priorities and the more detailed the priority setting, the lesser the remaining flexibility. Another factor with a negative relation to flexibility concerns the time and costs involved in reviewing and adapting the allocation decisions, including legal contestation.

Like in the Belgium-Flanders example, it can be most suitable to define certain priorities on a MS level to ensure compliance with the most relevant environmental and societal needs but leave abundant flexibility at the local/regional level to account for specific contexts and, most importantly, to allow a role for water pricing policies within the given allocated water volume. Both the top-down allocation mechanism and the performance of the lower-level water supply systems should be regularly reevaluated on their functioning and efficiency. This allows also for adaptation to changing hydrological and climatic conditions as needed.

Involve stakeholders

Engagement of stakeholders is highly relevant to identify regional needs and gain an overview of the impacts of water scarcity on different users. Stakeholder engagement shall address consumptive as well as non-consumptive uses such as navigation and recreation, as well as other water-related interests. Clarifying allocation priorities can give stakeholders planning security, as they know what to expect under scarcity conditions and can adapt and prepare (e.g., by adjusting their production processes).

Regarding the process of adapting water allocation regimes to climate change, it is not worthy that most water allocation regimes have grown over decades in a piecemeal fashion, making them rather poorly equipped for smooth adjustments to changing climatic conditions. Water allocation arrangements can be difficult to adjust if they have a high degree of path dependency that manifests itself in both institutional arrangements (law, property rights and policies) and long-lived water infrastructures, such as dams, canals and pipelines. **Adaptation challenges for water allocation regimes are further aggravated by the entrenchment of weak water policies** (non-respect of Article 9 WFD on pricing of water services; lack of regulating water uses; absence of effective controls of abstraction permits; tolerance of illegal water abstractions etc.), which then exacerbate structural water scarcity (OECD, 2022a).

80. Review and improve the (environmental) water permitting for abstractions, diversions in order to allow for flexible interventions to curb demand ahead of and during a crisis. This requires strong governance structures including monitoring and enforcing abilities.
81. Develop water allocations on the basis of ecological flow regimes and calculations of the water balance at river basin level.
82. Adapt water allocation schemes, taking into consideration climate change impacts and needs for adaptation, based on the OECD Health Check on water allocation mechanisms and CIS-guidance on ecological flows in the implementation of the WFD.
83. Establish a process for reforming (historic) water use rights to reflect changing scarcity and drought conditions and increased risks under climate change.
84. Ensure coordination of water allocation decisions with investments and sectoral policies and support adaptation of water uses to enhance resilience and minimise trade-offs.

8 NATURE-BASED SOLUTIONS FOR RESILIENCE & CLIMATE ADAPTATION

Nature-based adaptation focuses on ecosystem restoration and the enhancement of ecosystem services to protect society against the negative impacts of climate change, while at the same time increasing ecosystem resilience. Nature-based solutions (NBS) can be considered an 'umbrella concept' encompassing a range of established nature-based approaches, which aim to increase resilience to climate change (EEA, 2021a).

There is a broad consensus that NBS deliver multiple benefits, including better water retention capacity, climate change mitigation (mainly through carbon sequestration), biodiversity, water quality and water body conditions, coastal resilience, micro-climate regulation and air quality, and more sustainable communities. The multiple benefits of NBS found in 24 EU-funded projects are bundled in European Commission (2020). NBS bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. A recent report on the economic rationale of NBS in freshwater ecosystems (Deltares, 2021) illustrates that NBS save costs, contribute to multiple goals at once, often have an attractive socio-economic benefit, and can create jobs. Furthermore, NBS are beneficial for most of the Sustainable Development Goals (SDGs) (Faivre, 2017).

More specifically on water, NBS can substantially contribute to reducing the vulnerability of water management systems by enhancing the water retention capacity and by improving water quality and waterbody conditions. The water retention capacity refers to the natural sponge function of the soil and aquifers so that precipitation is collected, stored and slowly released over time. The capacity to improve water quality refers to the natural treatment and thus cleaning of polluted water, from agricultural and urban stormwater origin. NBS can also enhance hydromorphology and thus improve waterbody conditions. A review of the benefits of NBS for improving water quality and water body conditions, found in EU-funded projects, is published in Wild et al. (2020). The water retention and purification capacity of NBS are important functionalities to better prepare for droughts. Higher storage of better-quality water in natural, often underground water reservoirs results in alternative water access in case of drought.

NBS can be implemented at any scale, from large river restoration projects to small-scale urban infiltration reservoirs and green roofs. Large-scale projects, like Room for the River or some coastal marsh restoration projects, are typically directed to high-risk extreme floods, whereas local scale, often urban NBS, are intended to manage low-risk frequent floods. Some NBS are complemented with grey infrastructure to ensure water safety standards (e.g. reducing pollution of urban runoff before discharge). An overview of the knowledge base on NBS can be found on Climate ADAPT. The EU Guidance document on Natural Water Retention Measures (NWRM) (European Commission, 2014), developed by the CIS Working Group's PoM provides an overview of NWRM, which can be considered as NBS. NWRM include a wide range of measures and can be divided into two broad types.

Table 3: Illustrating the diversity of measures classified as NWRM (based on European Commission, 2014).

Type	Class	A non-exhaustive list of examples
Direct modification in ecosystems	Hydro-morphology (River, Lakes, Aquifers, connected wetlands)	Restoration and maintenance of rivers, lakes, aquifers and connected wetlands; Reconnection and restoration of floodplains and disconnected meanders, elimination of riverbank protection; enhancement of the buffering capacity of coastal saltmarshes and intertidal areas.
Change and adaptation in land-use and water management practice	Agriculture	Restoration and maintenance of meadows, pastures, buffer strips and shelter belts, soil conservation practices (crop rotation, intercropping, conservation tillage…), green cover, mulching and agroforestry.
	Forestry and Pastures	Afforestation of upstream catchments, targeted planting for “catching” precipitation; Continuous cover forestry; maintenance of riparian buffers; urban forests; Land-use conversion for water quality improvements and, drainage prevention

	Urban development	Green roofs, rainwater harvesting, permeable paving, swales, soak aways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration and, sustainable urban drainage systems.

8.1 Costs and benefits

The assessment of costs and benefits and monetising them is particularly complex in the case of NBS. For example, compared to the relative simplicity of calibrating the cost of building a new reservoir and allocating the regulated volumes to various objectives (flood protection and water available for specific users and the environment), there is the complexity of approximating the benefits and distributing the costs of a package of NBS with a similar expected contribution in terms of water availability and flood protection.

It is generally acknowledged that investing in NBS has a sound economic rationale to address flood and drought risks. The World Bank (2021) found that the benefits of flood investments that integrate NBS and early warning had the greatest benefits of all types of investments in disaster risk reduction. Using the Triple Dividend of Resilience Framework, the World Bank calculated very clear benefits of NBS for flood risk management in Europe with a median benefit-cost ratio of almost 5.

Even if the number of economic analyses comparing NBS with conventional alternatives in a river management context is limited, some available studies demonstrate that NBS can be economically attractive. To build a case for green solutions from a water balance improvement perspective, it is necessary to identify and quantify co-benefits as well, integrating their adaptive, multi-purpose and sustainable character so that the favourable impacts are appraised on an appropriate spatial and temporal scale (van Wesenbeeck et al., 2021). NBS often provide multiple co-benefits next to a primary objective, that can be of high relevance in overall and integrated management strategies. Many NBS are characterised by being adaptive to change as ecosystems can adapt to slowly altering conditions over time. For example, sedimentation in salt marshes can enable long-term adaptation to sea level rise, if enough sediment input is available for the sediment's vertical growth. Large-scale ecosystem restoration provides more resilient buffers to climatic instabilities using a catchment approach to flood management for NBS. It can also contribute to better resilience towards droughts and improve biodiversity in the conservation area (Penning, 2022).

Example 16: Aarhus River enabling infrastructure including real-time control systems

FP7 DESSIN's case study of the Aarhus River daylighting reports that enable infrastructure including real-time control systems costs ~€47 million with operating costs of ~600.000/year. The benefits of opening the river and resulting water quality improvements were calculated at €120 million. However, this valuation is limited to the benefit of opening the river in the central city and does not include the social benefits of water quality improvements to the lake, harbour and upper river between the lake and city centre.

Example 17: CBA of NBS in Italy

Liquete et al. (2016) report that NBS for water pollution control at Gorla Maggiore, Italy, performed equally or better than the alternative grey infrastructure for water purification and flood protection. Having a similar cost, the 'end of pipe' constructed wetlands to treat wastewater from combined sewer overflows, together with the surrounding park – provide additional benefits, including wildlife habitats and recreational opportunities.

The background document for CIS WG Floods provides recommendations on the use of economic methods for NBS for flood risk management (Cools & Interwies, 2023).

85. Scan both grey and NBS flood risk measures for their environmental and socio-economic long-term trade-offs. These trade-offs could align with the forthcoming scanning that is needed for a sustainable investment label, or in other words, to become EU taxonomy aligned.
86. Demonstrate the multiple benefits of NBS, in comparison to their costs, as part of the FRMPs and RBMPs, but also as standalone investment cases. Ideally, a cost-benefit analysis or multi-criteria approach is to be used.

8.2 Implementation challenges

The evaluation of the first FRMP (European Commission, 2019a) found that NBS are included in most plans, with various levels of ambition and specification. Yet, the dominance of grey infrastructure for flood risk management remains.

Despite the policy support for NBS, the multi-benefits of NBS for various EU policies, including the WFD and FD, and despite the increasing number of relevant projects, the gap for implementing NBS seems to remain large (and the implementation is often only at pilot scale). Causes for the limited prioritisation and implementation of NBS include:

i. The insufficient demonstration of their multiple benefits (in relation to their cost), makes a comparison to other (e.g. grey) alternatives difficult.
ii. The insufficient understanding of the benefits of NBS given the range of flood return periods. It is perceived that NBS are seldom sufficient to provide protection against high-risk extreme floods. The need to complement NBS with grey infrastructure can be a way forward.
iii. Insufficient scanning of the environmental and socio-economic trade-offs of conventional flood risk management measures.
iv. The use of social discount rates that give no or very low weight to long-term consequences. Many NBS have high initial costs but deliver long-term benefits.
v. Higher need for land adjacent to water bodies, which is scarce and costly to acquire. NBS need to be implemented on both public and private land. Investments in private land require negotiations with landowners.
vi. Limited information on the efficiency and climate robustness of NBS measures for the resilience of ecosystems against climate change, as the base for selection/prioritisation of NBS. Engineers' acquaintance and long-term experience with grey infrastructure.
vii. Limited awareness of best practices due to a lack of institutional guidance.
viii. Limited mobilisation of finances and arguments about high maintenance costs.

The potential impacts of climate change on NBS have not been adequately addressed in the literature so far (Seddon, et al., 2019). Like other ecosystems, NBS will also be affected by the impacts of a changing climate (Gómez, Máñez, & Máñez, 2020). It is known that changes in mean air and water temperatures, species distribution or precipitation patterns are highly likely to alter ecosystem functions and, thus, their ability to meet GES/GEP as well as NBS functionality. The long-term capability of NBS to deal with extreme weather events (such as droughts) may not be sufficient in a climate change context. Additionally, a significant part of the NBS research has been contextualised in cities. Usually, the urban-centred evidence on NBS effectiveness cannot be transferred to rural contexts (Gómez, et al., 2021).

87. Develop and implement practical design and implementation codes (standardisation codes) for NBS to help grey infrastructure engineers to also include NBS into their projects, while also offering guidance to ecosystem restoration workers.
88. Systematically examine NBS alternatives when rebuilding after a natural disaster (i.e. flood).
89. Develop standardised methods to calculate the costs and benefits of NBS.
90. Mobilise and combine financial resources, better use existing financial flows for NBS and/or blend finances of various sources for a common action plan on NBS.
91. Create Natural Water Reserves in the most water-stressed areas and apply NBS to protect and restore freshwater sources and the catchment areas in those reserves. Make those Natural Water reserves part of the water infrastructure, so that they can benefit from funding traditionally earmarked to infrastructure spending and make the protection and restoration of those Natural Water Resources of overriding public interest.

8.3 NBS supporting the implementation of WFD and FD

NBS can improve or preserve hydro-morphological conditions, coastal resilience, as well as water quantity and quality. A review of the multiple benefits of NBS has been recently released (European Commission, 2020a), together with another one, specifically reviewing the value of NBS for water quality and hydro-morphology (European Commission, 2020). The latter provides an analysis of EU-funded projects and includes a section on combined sewer overflows, and other water quality-related aspects of floods.

The FD states the FRMPs shall consider '…areas which have the potential to retain flood water, such as natural floodplains…' and that they may include the '…improvement of water retention…' (Article 7(3)). In the preamble, the FD asks FRMPs to 'consider where possible the maintenance and/or restoration of floodplains…'. The reporting guidance on the FD refers to NBS under 'measure type M31: Protection natural flood management/runoff and catchment management'. Measure M31 is defined as 'Measures to reduce the flow into natural or artificial drainage systems, such as overland flow interceptors and/or storage, enhancement of infiltration, etc. and including in-channel, floodplain works and the reforestation of banks, that restore natural systems to help slow flow and store water.'

Example 18: NBS supporting the implementation of WFD and FD in the Netherlands

The Ruimte voor de Rivier IJsseldelta project in the Netherlands is part of the national programme "Ruimte voor de Rivier" and includes 34 measures to improve the safety and aesthetics of Dutch river areas. The project aims to address water safety and contributes to various aspects such as economic development, public transportation, housing, nature conservation, agriculture, tourism, and water recreation. The results of the project include a water-secure and climate-resilient region, a new high-water channel named Reevediep, enhanced infrastructure, and the creation of new delta nature and bird habitats.

Example 19: NBS to reduce hydro-meteorological risks in rural and mountainous regions.

H2020 PHUSICOS investigates the use of NBS to reduce hydro-meteorological risks in rural and mountainous regions. The project delivers a 'receded green barrier' on the River Gausa, at Jorekstad near Lillehammer, Norway. Built using only natural and local materials, the barrier will contribute to water quality improvements to meet WFD objectives. Due to diffuse pollution impacts from agricultural land runoff, the river has only moderate ecological status with regard to total phosphorous, and a poor state in terms of total nitrogen. By creating a wetland and setting back the flood barrier the scheme is intended to prevent plastics and other substances from entering the river, as well as reducing nitrogen and phosphorous runoff, and mitigating the loss of fish habitats and spawning areas.

8.4 NBS and droughts

Flood risk mitigation-oriented NBS have usually secondary positive effects on resilience to droughts, as they increase natural water holding capacity. This is relevant as the number of NBS approaches targeting primarily floods is significantly larger than those targeting droughts (Sahani et al., 2019).

However, there are also NBS targeting specific droughts and water scarcity; for example, the prevention of and clearing of invasive alien trees has shown positive effects on drought-impacted streamflow (Holden et al., 2022). The installation of watering points can reduce wildlife losses during droughts (Sahani et al., 2019). Riparian trees are known to reduce water temperatures (Trimmel, et al., 2018). Furthermore, conservation agriculture, i.e. using combined methods of improved cultivation on arable land, has proven to be effective in reducing water stress by changing soil infiltration parameters (reducing bulk density and increasing organic matter) (Burek, et al., 2012).

More knowledge is however still needed on the long-term benefits of NBS. There is still low evidence, including the applicability of NBS to manage highly vulnerable ecosystems and in agriculture (IPCC, 2022).

Example 20: Co-creating 'healthy green corridor NBS' with citizens

H2020 URBINAT is co-creating a 'healthy green corridor NBS' with citizens in seven EU cities. At Porto in Portugal, this process includes the active participation of parish organisations and initiatives to involve local actors, resources and talents in designing and creating interventions. Also in Portugal, a €75m national programme has been commissioned to restore 5,000 km of freshwater streams, using NBS to help prevent forest fires, soil erosion, droughts and flooding, and to improve biodiversity and water quality. Within this programme, 1,000km length of rivers have already been restored (costing €11.5m) and a further 5,000km are targeted for restoration (costs €75m). The Minister of the Environment has highlighted that such NBS are part of the national effort to reduce emissions and mitigate against climate change and that NBS living labs in 16 different municipalities helped bring together civil engineers, local authorities, the forestry sector, and other businesses. Riverside 'parkways' connecting urban and rural communities represent important opportunities to achieve synergies between ecosystem restoration and social integration.

9 CROSS-BORDER/TRANSBOUNDARY ASPECTS OF CLIMATE ADAPTATION

Overexploitation and pollution of lakes, rivers, and aquifers can jeopardise ecosystem services across borders, but can also have negative impacts on certain economic sectors (e.g. agriculture or waterborne transport). Coastal resources can be jeopardised by upstream activities as depleted aquifers can allow saltwater intrusion in coastal areas and increase the concentration of arsenic fluoride and other toxic substances in ground waters needed by consumers and industry. A unilateral move by one country to build a dam could drastically reduce a river's flow downstream in another country. These transboundary aspects gain even more momentum under climate change.

Water management and adaptation within a transboundary basin are challenging and require strong cooperation between the riparian countries at different levels and with the water-related sectors, institutions, and other stakeholders with often conflicting and competing interests and needs. At the same time, transboundary cooperation can bring multiple benefits and make adaptation more efficient by sharing data, enlarging the planning scale, selecting better adaptation priorities, avoiding negative impacts of unilateral measures (maladaptation) as well as sharing costs and benefits. In addition, it also supports sustainable development and regional integration (UNECE, 2009). The European region is quite advanced in transboundary cooperation in climate change adaptation. For example, basins such as the Danube, the Dniester, the Neman and the Rhine have developed and implemented transboundary adaptation strategies and plans. Others, such as the Drin, the Meuse and the Sava integrate climate change issues while developing their RBM and FRMP (WMO, 2021).

A transboundary approach adds the requirements for MS to pool available data, models, scenarios and resources together to plan and adopt actions (UNECE & INBO, 2015). The common collection and exchange of information is an essential basis needed to develop an effective transboundary ecosystem-based climate change adaptation strategy. Joint or harmonised impact assessments, monitoring, and information systems such as databases or GIS systems are the key to eliminate conflicting results and policies (Rieu-Clarke, et al., 2015). The WFD and the FD both contain provisions for transboundary management and mainstreaming climate adaptation measures in a transboundary context:

- The **WFD** encourages MS to implement common principles to coordinate the efforts in the protection of water bodies and sustainable water use in terms of transboundary water problems (Preamble 35). MS shall ensure to assign affected river basins to an international river basin district and implement monitoring systems comparable to the community in order to develop programmes fitting to the objectives. Furthermore, there is the possibility for MSs to request the Commission to facilitate the establishment of the programmes of measures (Article 2 ((4&5)) (EU, 2000).
- The **FD** points out, that effective flood prevention and mitigation requires coordination between MS or third countries (Preamble 6). For transboundary rivers that means the development of FRMPs should not include measures which increase flood risks upstream or downstream of other countries unless these had been negotiated this way (Article 7((4)). Therefore, in a

transboundary context, MSs should coordinate to agree to a single or a set of common FRMPs (Article 8 ((2)) (EU, 2007).

To strengthen and simplify the cooperation between MS, this guidance document provides a short listing of good practices, which should be considered for a successful cooperation between riparian countries.

Preparing the ground for a transboundary cooperation

The process starts usually with the collaboration between the involved ministers of the riparian countries and the institutions responsible for the coordination, which ideally leads to an international cooperation body. Afterwards, the collaboration should be extended to other stakeholders. The aim is to bring climate experts, hydrology and ecology experts and political leaders together to support the development of an accurate picture of adaptation challenges and possible solutions at a transnational but also regional level. The first step in developing a common strategy or adaptation planning is usually a study on the climate change vulnerability of the river basin or region (Mekong River Commission [MRC], 2014). Besides setting up the process in a structured way, gathering first information, an estimation of human and financial resources is needed and the identification of potential sources for long-term funding should be made (Climate ADAPT, 2023a). The main factors determining the duration until the adaptation of the strategy are the availability of information and the extend of the mandate (e.g. a detailed versus a more generic strategy) (MRC, 2014).

Water diplomacy

Water diplomacy can be defined as the use of diplomatic instruments to existing or emerging disagreements and conflicts over international shared water resources with the aim to solve or mitigate those for the sake of cooperation, regional stability, and peace. Diplomatic instruments may include negotiations, dispute-resolution mechanisms, the establishment of consultation platforms, and the organisation of joint fact-finding missions. Technical instruments - such as establishing basin-wide management plans or joint monitoring networks - are not part of water diplomacy. While diplomatic and technical instruments often build on each other and can be directly linked, consistently defining water diplomacy merits this strict differentiation as will become clear later on (Schmeier, 2018). The Global Water Partnership provides a Toolbox for Integrated Water Resource Management including a tool about water diplomacy, that explains several tracks that can be used in water diplomacy and introduces regional and basin dialogue pathways for water diplomacy.

Example 21: The Albufeira Convention between Spain and Portugal

The Albufeira Convention, signed in 1998, is the legal instrument that articulates the cooperation mechanisms between Spain and Portugal for the protection of surface and groundwater and the aquatic and terrestrial ecosystems directly dependent on them, as well as for the sustainable use of the water resources of the Spanish-Portuguese hydrographic basins. There are five river basins shared between Spain and Portugal (Minho, Lima, Douro, Tagus and Guadiana), integrated in four international RBDs. The shared basins occupy 46% of the territory of the Iberian Peninsula - 64% of Portugal and 42% of Spain. This agreement culminates a long history of establishing partnerships and treaties regarding those rivers dating back to the 19th century, mostly to define boundaries and uses of the rivers' bordering stretches. The Convention was revised in 2008 to reinforce the sustainable water management, according to the WFD. The Albufeira Convention addresses new challenges arising from the WFD and the current state of shared basins, including water quality and resource availability during drought periods. In practice, beyond the formal structures, the Convention's cooperation mechanisms are based on a regular and systematic exchange of information, consultations and activities within the Technical Secretariats and the Convention, and the people engaged in the working groups, and the adoption of technical measures in a spirit of good cooperation.

Development of data exchange mechanisms

The next step includes the development of new applications of existing mechanisms to exchange information between the involved countries. This includes the standardisation of already used but also of newly collected data like impact assessments, monitoring or information systems to guarantee efficient cooperation (UNECE & INBO, 2015). A successful approach to exchange data is also a way to reduce costs.

Example 22: Data and information sharing

International Meuse Commission (IMC) was established in 2002 with the objective of achieving sustainable and integrated water management of the international Meuse River basin. The agreement was signed by the Walloon Region, the Netherlands, France, Germany, the Flemish Region, the Brussels-Capital Region, Belgium, and Luxembourg, and it came into effect on December 1, 2006. Therefore, a coordination platform was established to ensure the transmission of necessary information like the implementation of protection measures against and the prevention of the negative effects of floods and droughts.

Management of the international river basins

For successful cooperation on climate change adaptation within a river basin, appropriate institutional arrangements and principles of integrated water resource management are necessary. Therefore, a framework like a transboundary agreement is an important mechanism for solving disputes and can support the development and implementation of adaptation strategies and measures. A good example is provided by the river basin of the Danube. The Danube cooperation area stretches from Germany crossing 14 states up to the estuary in Romania. The cooperation includes a set of common policy frameworks like the Danube RBMP, the Danube Flood Risk Management Plan and the Strategy on adaptation to Climate Change. The latter includes guidance on the integration of climate change adaptation processes, and the promotion of multilateral and transboundary cooperation action and serves as a reference for national policymakers and other officials (Climate ADAPT, 2023a).

Besides a common agreement, the implementation of a basin organisation to get a coordinated overview of the activities and formulate the strategy is essential. The organisations should harmonise tools, methods, models and scenarios to be used and to prepare a basin-wide assessment in a good way. Useful initiatives include the establishment of dedicated working groups on adaptation or integrating adaptation into other relevant working groups within a transboundary organisation. On the content level, it is important to include experts from all riparian countries to have a diverse input of knowledge (UNECE & INBO, 2015). Although transboundary agreements and organisations play a crucial role in climate change adaptation, transboundary basins, where such agreements and organisations are not in place yet, can establish less formal mechanisms of transboundary cooperation to develop, coordinate and implement adaptation strategies. Such more technical cooperation can even result in broader and more formal transboundary cooperation. For example, in the Dniester basin shared by Moldova and Ukraine, joint activities on transboundary climate change adaptation (namely the development of the joint adaptation strategy and its implementation plan) facilitated the entry into force of the transboundary agreement and establishment of the dedicated Commission (UNEP, 2021). Following a gendered balance approach through evidence-based policies informed by gender-disaggregated data, the inclusion of a gender perspective in the consultation and decision-making process, and the promotion of gender-sensitive beneficiary groups in the management is recommended (Rieu-Clarke, et al., 2015).

Methods and tools used

Climate change effects are just one of the pressures, other pressures do exist (economic, demographic, etc.) (UNECE & INBO, 2015). A useful tool to rate climate-related impacts or other pressures and develop procedures for analysing adaptation options or strategies can be the application of a Multi-criteria analysis. In order to gain an accurate picture of the successful performance of the measures a Monitoring, Reporting and Evaluation (MRE) system using an approach combining quantitative and qualitative methods is needed to support the process. This allows robust, consistent and contextualised analyses of the performance of the implemented measures (Climate ADAPT, 2023a). As a good practice example, the cooperation of the Danube Basin developed a platform called 'Climate Change Adaptation Measures Toolbox' where possible adaptation measures are provided and categorised in different fields and types.

Implementing the adaptation plan or strategy

The adaptation plan or strategy sets out what needs to be done to convert options into actions, specifying roles, responsibilities, timing, and addressing resource needs and allocation. It guides the process by providing a detailed roadmap for putting measures into practice (Climate ADAPT, 2023a). To raise the effectiveness and reduce the occurrence of physical or institutional barriers, the implementation of the adaptation plan or strategy should be adopted with other relevant policies. The acceptance and compatibility with other policies as well as river basin and FRMP is important to ensure appropriate funding and the realisation of at least a part of the strategy measures. A framework can serve as a conflict prevention tool between riparian countries, by addressing national legal weaknesses and establishing a fair playing field for weaker and stronger neighbours by setting minimum substantives and procedural rules to be followed (Rieu-Clarke, et al., 2015). To avoid future conflicts the existence of a strong policy framework in times of climate change will become even more important because the more frequent occurrence of extreme events (e.g. droughts) will evoke challenges like the possible default of water delivery agreements between basin countries.

The implementation of measures should be prioritised where the entire basin can benefit from. For instance, if an upstream country takes flood reduction measures, the downstream country may benefit from this or if a downstream country expands its waterway the upstream country may be granted access and benefit as well. Therefore, it is useful to cooperate and share benefits and costs between riparian countries to improve efficiency (UNECE, 2020). However, issues, social costs or the transfer of vulnerability within the basin to another location should be avoided. Measures with low or no regret potential should be realised at the beginning, while the assessments on the scenarios and uncertainty trajectories are still running. It is moreover important to rely the risk management on local knowledge and not necessarily implement instruments blindly (Rieu-Clarke, et al., 2015).

92. Ensure a cross-sectoral approach when selecting adaptation actions including the transboundary level, in order to prevent possible conflicts between different sectors and to consider trade-offs and synergies between adaptation and mitigation measures.
93. When planning adaptation across boundaries, focus on preventing negative transboundary impacts, sharing benefits and risks equitably and reasonably and cooperating based on equality and reciprocity.
94. Ensure that data and information related to water availability, water characterisation and water needs, including that from early warning systems, is shared between countries and sectors as this is essential for effective and efficient climate change adaptation across transboundary basins. Make policy coordination truly operational via international agreement, if possible.
95. Enable the sharing of costs (and benefits, as mentioned above) for climate adaptation measures, taking into account the risk entailed on each side.
96. Give more attention to direct and indirect socio-economic effects at border areas (e.g. lost/new jobs, change in utilities, etc)
97. Bolster enforcement community at the transboundary level (building on enforcement trust relationship)

10 HOW TO DO A CLIMATE CHECK OF MEASURES (ADAPTATION AND MITIGATION)?

The overall aim of the climate check is to ensure that the water management measures stipulated in RBM and FRM plans are sufficiently adaptive to future climate conditions. It could contain two main steps that address two different levels: the PoM level and the individual project level:

- Step 1: Screening phase for Key Type Measures (KTMs). The screening phase should provide a form of sensitivity analysis for the selection of measures that are effective, robust and cost-efficient under changing conditions and are in line with RBMP objectives/FRM objectives and climate goals. The selected measures should ensure that the water management objectives are met in a future that is impacted by climate change.
  Generally, only measures that are robust to climate change impacts and do not contribute to amplifying climate change and its impacts should pass the climate check and should be considered. As RBMP and /or FRM planning involves hundreds of measures it is impossible to check each of them at each location. Therefore, this check is proposed on KTM and sub-KTM levels. The appropriate level needs to be defined by the competent authority.

- Step 2: At the implementation stage detailed proofing for single measures in particular for the development of infrastructure projects is done. This process integrates climate proofing with project cycle management (PCM), environmental impact assessments (EIA), and strategic environmental assessment (SEA) processes following the Commission Notice Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (2021/C 373/01). This is particularly important when measures have a long lifetime and are cost-intensive and when assessing whether these measures are still effective under the likely or possible future climate change scenarios and different adaptation pathways.

10.1 Step 1: Screening phase for KTMs and Sub-KTMs at PoM level

The structure of the check to be performed by the competent authority primarily includes two areas ('assessment areas') that are of main relevance: climate robustness and contribution to climate change. Each assessment area is then broken down into several topics which are assessed along a set of questions[32].

Assessment area	Topic	Short explanation
Climate robustness	Topic 1: Relevance of the measure	It examines the relevance of the measure under changed climatic conditions.
	Topic 2: Effectiveness of the measure	It examines the effectiveness of the measure under changed climatic conditions.
	Topic 3: Flexibility and reversibility of the measure	It examines how flexible the measure is and how it can be adjusted to changed climatic conditions.
	Topic 4: Side effects	It examines if the measure has positive or negative effects on other ecosystems or activities within water management relevant sectors in the future.
Contribution to climate change	Topic 5: Intensification of climate change	It should examine if the measure intensifies climate change, e.g. it leads to a release of additional GHG[33].

10.1.1 Application: Assessment area 1 'Climate Robustness'

In many areas due to the long-term changes in precipitation regimes, as well as the change in frequency of extreme events caused by climate change, a climate check of measures could be

[32] This approach has been developed by the German Federal Environmental Agency.

[33] During the development of the Screening Tool methodology, it was also discussed how to determine if a measure intensifies climate change impacts. Due to the complexity of the causation between climate change - measure - effect and the difficulties in the assessment, this aspect was not included. In addition, taking into account the WFD principle of preventing any deterioration in status, no measures may be taken that worsen the condition of a body of water. This also applies to changing climatic conditions.

included in the WFD management plans, DMP and the FRMP and would be an important task for public administrations.

The first assessment area determines the **climate robustness** of a water management measure under changing climatic conditions based on different criteria.

Topic 1: Relevance of the measure

Information for the assessment of the following question should be included in the chapter dealing with the aspect of 'Future Developments' of the RBMP.

How does the relevance of the measure change regarding the water management objective taking into account the (previously identified) climate consequences?

Description: The question about the relevance of a measure assumes that certain water management measures completely lose their relevance in the future – once the projected future climate changes occur – or could gain relevance concerning the water management objectives. This needs to be particularly considered to reach GES/GEP or the set flood management objectives.

Example: There will be increased erosion and higher concentrations of nutrients in waterways caused by more frequent and intense rain events. Measures like riparian buffer strips are therefore even more relevant in the future. The same applies to measures dealing with flood protection/flood risk management. The dimensions/designs of overflow basins for rainwater regarding increased and/or heavier rain have to be reconsidered because their relevance would increase in such a case.

Assessment scheme: A separate assessment must be carried out for each identified change in the climate hazard system (drought, flood, heavy rain, low water levels, storm surges, changes in the groundwater level/recharge including groundwater flooding, as well as air and water temperature increases).

Relevance strongly decreases			Relevance does not change			Relevance strongly increases
-3	-2	-1	0	+1	+2	+3

Topic 2: Effectiveness of the measure

This Topic is assessed based on multiple questions:

Does climate change alter the effectiveness of the measure regarding the water management objective?

Description: This question determines if the effectiveness of a measure changes with respect to the water management goal under the projected climatic changes.

Example: Due to higher air temperatures in the future, the cleaning performance of sewage treatment plants will increase (i.e. their effectiveness increases – greater loads will be treated).

Assessment scheme: A separate assessment should be carried out for each identified change in the climate system.

Effectiveness strongly decreases			Effectiveness does not change			Effectiveness strongly increases
-3	-2	-1	0	+1	+2	+3

How do the maintenance costs of the measure change due to the projected climate change impacts?

Description: This question should be used to examine the changing operating costs, i.e. the costs of maintenance of the measure.

Example: Based on more frequent or stronger flood events, the costs for preservation and maintenance of flood protection measures or the costs to maintain water infrastructures that will transport less water due to a lower water level may increase. Increased drainage, however, may also lead to stronger sediment transport and increased shore erosion and therefore cause increased costs in river maintenance.

Assessment scheme:

Costs strongly increase			Costs do not change			Costs strongly decrease
-3	-2	-1	0	+1	+2	+3

Topic 3: Flexibility and reversibility of the measure

How far can the measures be adjusted/modified in case of more frequent and intense extreme events (including quick changes between different events (e.g. droughts and floods)?

Description: This question examines if the measure can be adjusted to changes in the climate system such as the more frequent occurrence of drought and floods and the close occurrence of both after each other. This is geared towards the ‘technical’ adjustment or modification of an existing measure at a later point in time.

Example: Low flexibility means that a measure may only be adjusted with very high expenses or costs (for example, ‘costs for the adjustment’ correspond to the ‘costs for construction’ of the measure). With medium flexibility, the measures may be adjusted under certain prerequisites, for example, the increase in the height of dikes or the construction of additional retention areas for flood management. On the other side, high flexibility occurs where measures can be adjusted without considerable costs, like for certain measures in mobile flood protection or early warning systems.

Assessment scheme:

Only adjustable with very high expenses						High flexibility
-3	-2	-1	0	+1	+2	+3

Does the measure have installed/planned safety margins that guarantee the function of the measure regarding its water management goal under changing climate?

Description: The question examines if during the planning/design of the measure, the expected climatic changes were considered by integrating safety margins and therefore the water management objective of the measure can be reached with higher probability.

Example: During the assessment of flood protection measures, a factor for climate change was considered. Flood design discharge has been increased beyond the statistically determined data (e.g. HQ100).

Assessment scheme:

Safety margins not present	Safety margins are not important for the measure	Safety margins present
-3	0	+3

Is the measure also reasonable if climate change does not develop as given by currently available climate projections (so-called ‘no-regret’ or ‘low-regret’ measures)?

Description: The question examines if the measure should be considered reasonable despite climate projections do not pan out, i.e. if the measure is reasonable independent of climate change (so-called ‘no-regret’ or ‘low-regret’ measures).

Example: Examples of low and no regret measures are the existing limitation of new construction in areas at risk of flooding (because these are in a risk zone independent of climate change) or the creation of protected areas/natural retention areas (because these also help to achieve biodiversity goals). Other examples of low/no-regret measures include the reduction of leakage in the water infrastructure or all measures that lead to a decrease in water demand (see attachment).

Assessment scheme:

No low-regret/no-regret measure	Low-regret/no-regret measure
0	+3

Topic 4: Side effects and co-benefits

Does the measure improve/worsen the resilience of ecosystems compared to the projected climate change impacts?

Description: This question examines if the measure improves or worsens the resilience of ecosystems against climate change compared to the projected climate change impacts.

Example: Climate change and its consequences may have effects on the functionality of ecosystems, for example through a change in water and temperature/other physico-chemical regimes. This may result in changes of the species composition. A water management measure may strengthen or weaken the resilience of affected ecosystems; thus, a measure that increases the temperature of waterways (e.g. wastewater flows into water courses with increasingly low water) would lead to worsening resilience of the surrounding ecosystems. The opposite applies to a measure that increases the water quantity available (e.g. through savings). Measures that lower the flow of hazardous substances and nutrients into ecosystems (like riparian buffer strips or the expansion of treatment plants) increase their resilience.

Assessment scheme:

Strongly reduces resilience			Resilience does not change			Strongly increases resilience
-3	-2	-1	0	+1	+2	+3

Is this measure optimising its potential to support adaptation objectives?

Description: To foster synergies of water and climate adaptation, it is not only necessary to look at the conformity of reaching objectives (and not to amplify climate change – see assessment area 2), but also to design planned measures in such a manner that it achieves the intended objective while optimising its potential to support climate protection and adaptation objectives or to bring other co-benefits.

Example: The restoration of an urban river stretch to improve hydromorphology could also be carried out in a way that reduces urban heat island effects.

Assessment scheme:

Maladaptation if the measure is possible/given	No support for climate change adaptation	High support for adaptation to climate change
-3	0	+3

Is this measure coherent with an existing climate adaptation strategy in place at a high governmental level?

Description: A central question for the assessment of measures is their coherence with a possibly existing climate adaptation strategy (e.g. at the national level). The selected measures should ideally agree with such a strategy.

Example: The creation of natural retention areas for floods and nature protection on agricultural land represents, for example, a conflict of use. This measure is considered coherent with a climate adaptation strategy, for example at the national level, if the strategy calls for the expansion of natural retention spaces.

Assessment scheme:

No coherence with adaptation strategies at a high governmental level	No information / no high-level adaptation plan	High coherence with adaptation strategies at a high governmental level

-3	0	+3

10.1.2 Application: Assessment area 2 'Effects on climate change'

This second assessment area deals with undesired feedback of the measure contributing to amplifying climate change and its impacts.

Topic 5: Intensification of climate change

Does the implementation of the measure lead to the direct emission of greenhouse gases (GHG)?

Description: Many water management measures (for example under the management plans of the WFD and the FD) can amplify climate change by, e.g., directly releasing GHG throughout their lifespan.

Example: Wastewater treatment plants without gas caps directly emit methane during operation. On the other side, the reforestation or restoration of wetlands (e.g. for flood protection) may permanently absorb and retain carbon dioxide (CO_2-reduction).

Assessment scheme:

High GHG emissions	Medium GHG emissions	No/low GHG emissions	Medium CO_2-reduction	High CO_2-reduction
-3	-2	0	+2 (e.g. wet meadows)	+3 (e.g. peatlands)

How high is the energy consumption of the measure during its operation (indirect contribution to climate change)?

Description: This question examines the energy consumption of the measure or its maintenance during its operation and corresponds to its indirect contribution to the emission of greenhouse gases.

Example: When answering the question, the entire lifespan of the measure should be considered. If the measure consumes significant quantities of energy, it should be evaluated as a generally high greenhouse gas emission.

Assessment scheme:

High energy consumption during operation	Medium energy consumption during operation	No/low energy consumption during operation
-3	-2	0

10.2 Step 2 Detailed proofing of infrastructure projects

Climate proofing on the project level integrates climate change mitigation and adaptation aspects into the development of infrastructure projects when implementing measures set out in the RBMPs. The Guidance document understands infrastructure as a broad concept addressing different type like buildings, nature-based infrastructure, network infrastructure, systems to manage waste, or other physical assets. However, it makes sense to carry out detailed reviews, especially for larger infrastructure projects with a long lifespan, high investment costs, and impact on the environment in order to limit the bureaucratic effort.

The process of climate proofing is integrated into project cycle management (PCM), environmental impact assessments (EIA), and strategic environmental assessment (SEA) processes and follows the 'Technical guidance on the climate proofing of infrastructure in the period 2021-2027' of the Commission". It enables users to make informed decisions on projects that qualify as compatible with the Paris Agreement and EU climate objectives, which means it is consistent with a credible GHG emission reduction pathway in line with the EU's new climate targets for 2030 and climate neutrality by 2050, as well as with climate-resilient development. The application of the guidance is mandatory for European projects falling under the Common Provisions Regulation as well as under the Recovery and Resilience Facility. There are two pillars (mitigation and adaptation) and two phases (screening and detailed analysis), which are illustrated in the following figure and after further detailed (European Commission, 2021).

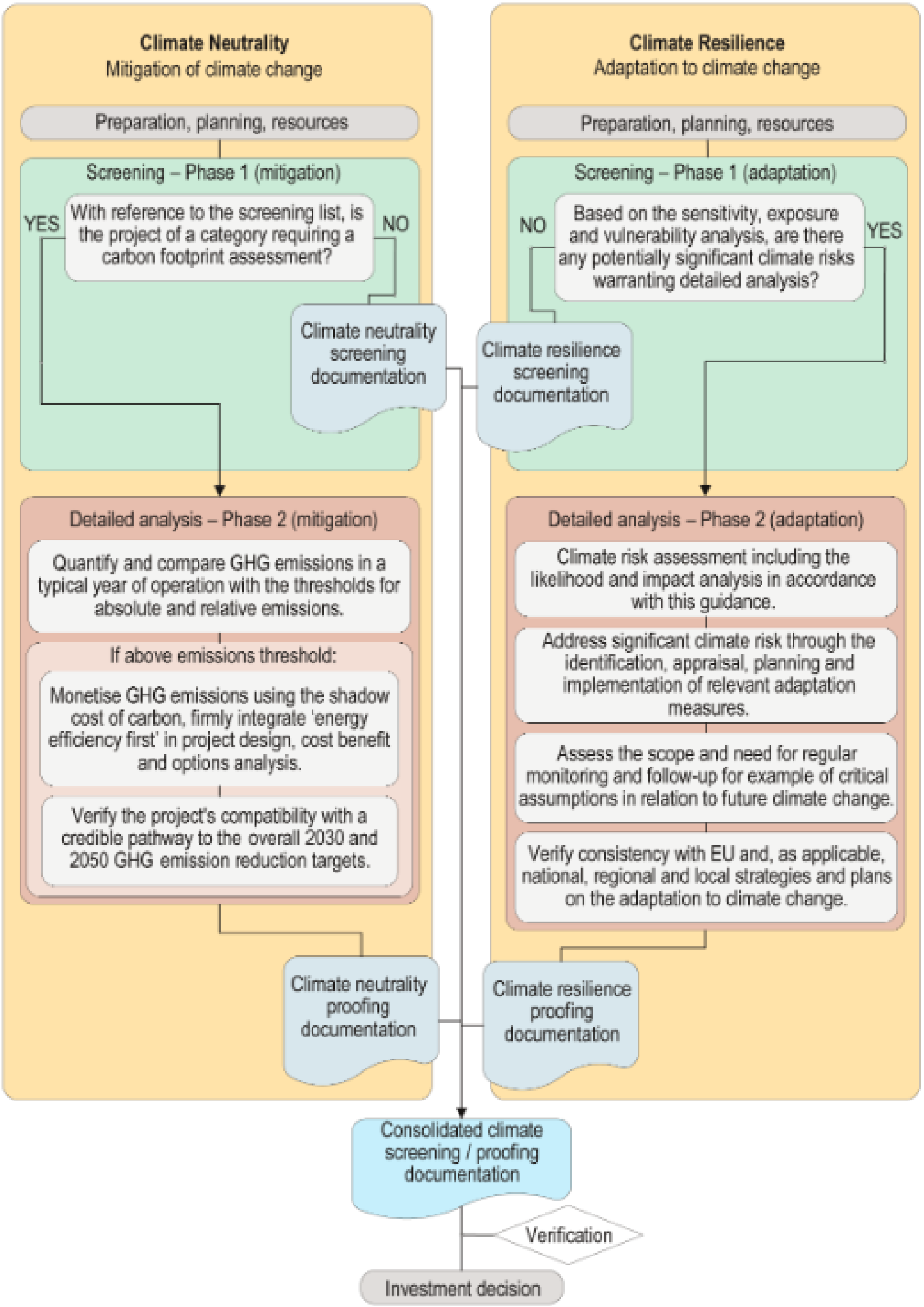


Figure 7: Climate proofing and the pillars on 'climate neutrality' and 'climate resilience' (European Commission, 2021).

10.2.1 Climate Neutrality – Mitigation of climate change

Preparation, planning and resources:

An early-stage and consistent assessment of expected greenhouse gas emissions over the many development stages of a project helps to mitigate its impact on climate change. There is a range of choices that can be made during the planning and design stages that may affect the project's GHG emissions over its lifespan, from construction and operation until decommissioning. In certain sectors (e.g. transport, energy and urban development), it is mainly at the planning level that effective actions must be taken to reduce GHG.

Screening – Phase 1 (mitigation):

In the first phase, the project should be examined with respect to the mandatory/optional carbon footprint assessment. Such an assessment is required, e.g., for heavy industry, power plants, and landfills. Whereas, it is not required for telecommunication service, drinking- and rainwater supply networks.

- If the project does not require a carbon footprint assessment, summarise the analysis in a climate neutrality screening statement, which in principle (funding-specific requirements on, e.g. the cost-benefit analysis may include GHG emissions) gives a conclusion on climate proofing with regard to climate neutrality.
- If the project requires a carbon footprint assessment, proceed to phase 2.

Detailed analysis – Phase 2 (mitigation):

If this phase is mandatory, quantify GHG emissions in a typical year of operation using the carbon footprint method. It is recommended to use, where applicable, the EIB carbon footprint methodology (to quantify GHG emissions) and the EIB shadow cost of the carbon method (to monetise GHG emissions). Then they should be compared with the thresholds for absolute and relative GHG emissions (threshold >20.000 tonnes CO_2e/year [positive or negative]). If the GHG emissions exceed any of these thresholds, carry out the following analysis:

- Monetise GHG emissions using the shadow cost of carbon (a continuous increase from 80 euros in 2020 to 800 euros in 2050 per ton) and then integrate the ‘energy efficiency first’ principle[34] in the project design, options analysis, and the cost-benefit analysis.

- Verify the project’s compatibility with a credible pathway to achieve the overall 2030 and 2050 GHG emission reduction targets. For infrastructure with a lifespan beyond 2050, the project’s compatibility with operation, maintenance and final decommissioning under conditions of climate neutrality should be acknowledged.

10.2.2 Climate Resilience – Adapting to climate change

Preparation, planning and resources:

Infrastructure is usually long-lasting and may be exposed to a changing climate for many years with increasingly adverse and frequent extreme weather and climatic impacts. It is recommended to integrate the climate vulnerability and risk assessment from the beginning of the project development process, including EIA because this will generally provide the broadest range of possibilities for selecting the optimal adaptation options. For example, the project location, which is often decided at an early stage, can be decisive for a climate change vulnerability and risk assessment. There will usually be more constraints when the assessment is initiated later in the project development, which could lead to suboptimal solutions being chosen. In addition to factoring in the climate resilience of the project, there must be measures to ensure that the project does not increase the vulnerability of neighbouring economic and social structures. This could happen, for instance, if a project includes an embankment that could increase flood risk in the vicinity.

Screening – Phase 1 (adaptation):

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[34] Emphasises the need to prioritise alternative cost-efficient energy efficiency measures when making investment decisions, in particular cost-effective end-use energy savings.

The first step is to carry out a climate **sensitivity** (ranking of the relevant climate variables and hazards for a given project type), **exposure** (ranking of the relevant climate variables and hazards for the selected location) and **vulnerability** (summarises the sensitivity and exposure analysis) **analysis**:

- If there are no significant climate risks warranting for a further analysis, compile the documentation and summarise the analysis in a climate resilience screening statement, which in principle gives a conclusion on climate proofing with regard to climate resilience.
- If there are significant climate risks warranting for a further analysis, proceed to phase 2 below.

Detailed analysis – Phase 2 (adaptation):

The next step is to carry out a **likelihood** (summarises likelihood of climate variables and hazards in a qualitative or quantitative way) and **impact** (potential impact of the climate variables and hazards) **analysis** which is concluded in the climate **risk assessment** (detailed summary of likelihood and impact analysis, including the explanation and quantification of risk levels):

- Address significant climate risks by identifying, appraising, planning and implementing relevant and suitable adaptation measures.
- Assess the scope and need for regular monitoring and follow-up, for example, critical assumptions in relation to future climate change.
- Verify consistency with the EU and, as applicable, national, regional and local strategies and plans on the adaptation to climate change, and other relevant strategic and planning documents.

The documentation and the analysis should be summarised in the climate resilience proofing statement, that gives a conclusion on climate proofing with regard to climate resilience on which the decision is made.

98. Perform a climate check of the water management plans and programmes to:
    a. Ensure Climate Resilience: Climate proofing helps water management programmes become more resilient, capable of adapting to these changes and minimising risks associated with unpredictable and severe weather conditions.
    b. Protect Water Resources: By climate-proofing water management, these programmes can better protect and preserve water sources, ensuring sustainable access to clean water for various purposes, including drinking, agriculture, and industry.
    c. Mitigate Risks of Flooding and Drought: Climate-proofing allows water management programmes to prepare for and mitigate the risks associated with both flooding and drought.
    d. Preserve Ecosystems: A robust climate-proofing strategy in water management helps to protect ecosystems that rely on water bodies. Maintaining an ecological balance ensures the safeguarding of biodiversity, which, in turn, supports various ecosystem services crucial for human well-being.
    e. Improve Infrastructure Planning and Maintenance: Climate-proofing helps in planning, constructing, and maintaining water infrastructure that can withstand changing climatic conditions, reducing the vulnerability of water-related structures

	to extreme weather events and rising sea levels. It also helps to ensure that costly investments will also work in the future.

11 ANNEX I: ADAPTATION ACTIONS/MEASURES – SOURCES OF INFORMATION

11.1 General measures

Climate change is affecting water management in different ways. Therefore, the EU provides and supports several information tools for MS where they can get and exchange information and good practice examples.

Name	Description
WISE	The Water Information System for Europe (WISE) provides information and resources to adapt water resources to climate change.
Climate-ADAPT	The website aims to support Europe in adapting to climate change and provides information and tools that can be used to adapt states, regions, urban and rural areas to tackle water-related issues.
NWRM	The Natural Water Retention Measures promotes actions that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes.
DRYvER	The project aims at developing strategies to mitigate and adapt to climate change effects in drying river networks, integrating hydrological, ecological (including NbS), socio-economic and policy perspectives.
EFAS	The Copernicus European Flood Awareness System (EFAS) provides probabilistic flood alert information more than 48 hours in advance, which is used by emergency managers across Europe.
EDO	The Copernicus European Drought Observatory provides drought-relevant information and predictions
LISFLOOD	The LISFLOOD model, developed by the JRC of the European Commission, is a hydrological rainfall-runoff model capable of simulating the hydrological processes that occur in a catchment.

The EU published a series of reports concerning water-related topics.

i. European climate risk assessment
The EUCRA report builds on and complements the existing knowledge base on climate impacts and risks for Europe, including recent reports by the Intergovernmental Panel on Climate Change, the Copernicus Climate Change Service and the Joint Research Centre of the European Commission, as well as outcomes of EU-funded research and development projects and national climate risk assessments.

ii. Climate change impacts and adaptation in Europe
The report includes several chapters related to water resources, concluding that droughts will happen more frequently, last longer and become more intense, especially in southern and western parts of Europe. Furthermore, river and coastal floods are likely to increase.

iii. Climate change and Europe’s water resources
The report delivers projections of future water resources, due to climate change, land use change and changes in water consumption.

iv. Global warming and drought impacts in the EU
The report concerns the more frequent occurrence of droughts and their increasing intensity. Furthermore, it estimates the annual economic loss in different climate change scenarios.

v. Global warming and human impacts of heat and cold extremes in the EU
The report addresses the rising frequency of heatwaves and the resulting damage it causes economically but also leads to rising mortality due to these extreme conditions within citizens.

vi. Adapting to rising coastal flood risk in the EU under climate change
The report concerns the adaptation measures that could be taken to mitigate and lower the damage caused by sea level rise in coastal areas.

vii. Adapting to rising river flood risk in the EU under climate change
The report addresses the growing flood risk in river basins due to climate change and how building-based damage reduction measures and the reduction of flood peaks using retention areas can be implemented to lower the impacts in a cost-efficient way.

viii. Quantitative and qualitative aspects of water safety under a changing climate
The report addresses the critical nexus between drinking water availability and various factors affecting freshwater, including extreme weather events and slow-onset climate changes. It conducts a rapid review and qualitative rating of issues such as urban land cover, agricultural activities, water storage, water abstraction, and infrastructure, identifying them as key contributors to medium-high risks of climate change impact, with water abstraction posing the highest risk.

11.2 Urban measures

European cities are already facing a number of climatic disasters (e.g. heat waves, river floodings, pluvial floods, and water scarcity). Due to the ongoing climate change and the intensification and frequency of extreme events, cities need to identify their vulnerability to these hazards and adapt their adaptive capacity accordingly. To support urban areas in the implementation of measures there are resources provided with good practice examples on how to adapt.

Name	Description
SCOREwater	The project aims to introduce digital services to improve the management of wastewater, stormwater and flooding events to enhance the resilience of cities against climate change.
Urban Storm	The LIFE project facilitates the development and implementation of integrated approaches for climate change adaptation strategies and action plans to increase the climate resilience of Estonian municipalities, especially their ability to manage flash flooding.

SPONGE 2020	The project produced a toolbox, a guidance package and a cross-border action plan to support stakeholder engagement and participative actions in climate change adaptation to better manage urban flooding.

11.3 Rural measures

Rural areas in the EU are sensitive to changes in the water balance. A change in water availability affects not only the local inhabitants, who are dependent on resilient water resources but also the ecosystems. Climate change is leading to an increase in heavy rain and longer drought events, which lead to a rising problem of water scarcity, crop failures, forest fires, floods and pressure on biodiversity. Therefore, water-related resources for a better understanding and good practice examples are provided.

Name	Description
RECONECT	The project aims to rapidly enhance the European reference framework on NbS for hydro-meteorological risk reduction by demonstrating, referencing, upscaling and exploiting large-scale NbS in rural and natural areas.
OPERANDUM	The project works on the reduction of hydro-meteorological risks in European territories through co-designed, co-developed, deployed, tested and demonstrated innovative green and blue/grey/hybrid NbS.

12 ANNEX II EXAMPLES OF THE IMPACT OF CLIMATE CHANGE ON THE QUALITY ELEMENTS

Example 23: Increasing brownification of lakes in Northern Europe: Lake Bolmen in Sweden, moving from low to high colour.

Water Category: Lakes
BQE methods: Phytoplankton, Macrophytes

Climate change in combination with less acid rain and changes in catchment vegetation have caused brownification of lakes in particular in northern Europe (Finstad et al., 2016). This increased flux of humic substances into rivers and lakes, as well as to downstream estuaries and coastal waters can alter aquatic geochemistry and light climate. This impacts the structure and functioning of aquatic systems, for example altering phytoplankton composition, sometimes increasing nuisance species such as *Gonyostomum semen* or leading to a reduction of benthic macrophytes such as isoetids and favouring species that can grow taller in the water column such as eloedids (Mormul et al., 2012; Kritzberg et al., 2020). This has important implications for WFD assessment, as the humic state is used in the type description for rivers and lakes in the Northern inter-calibration group as well as the Baltic Sea.

Example 24: The Italian deep subalpine lakes - cascading effects from increased winter temperatures, reduced mixing and altered nutrient dynamics.

Water Category: Alpine Lakes

BQE methods: Italian Phytoplankton Assessment Method (IPAM), BQIES (Benthic Quality Index Expected Species number)

The deep subalpine lakes are of key economic importance in northern Italy and their size and depth make them a key regional water resource requiring priority management (Premazzi et al., 2003; Regione del Veneto, 2018). A warming trend has been detected in the lakes with annual average surface temperatures increasing by 0.017 °C yr^{-1} and 0.032 °C yr^{-1} in summer (Pareeth et al., 2017). This has led to more stable stratification and increasing isolation of the hypolimnion from the epilimnion, altering nutrient dynamics, with no complete mixing since 2006. This has led to a gradual decrease in oxygen concentrations in the hypolimnion with the result that climate now exerts more control on oxygen than trophic status (Rogora et al., 2018). This, in turn, has also reduced nutrient transfer from the hypolimnion to the epilimnion resulting in alterations to phytoplankton composition (Salmaso et al., 2018).

While in some cases, chlorophyll-a may decline with continued stratification, superficially indicating an improvement, the composition of the phytoplankton community may change or other biological quality elements such as macroinvertebrates in the sub-littoral and profundal zones may deteriorate given the lower oxygen concentrations below the thermocline (Rossaro et al., 2007). An issue of future concern is a possible mixing event that may deliver to the surface layer water with low oxygen and high nutrients. Quantifying the relative role of altered stratification, nutrient loading and their interaction for diverse BQEs remains a challenge. Climate change may therefore create pressure to alter management targets and strategies as the lake typology (e.g. typology system B: mixing characteristics) and, therefore, ecological status boundaries may effectively change, presenting a stark choice between setting unobtainable goals and the need to protect and improve water quality (Cardoso et al., 2009).

Example 25: Science challenge – Developing an approach that maintains the integrity of the WFD assessment system in a changing climate.

Further research, including modelling, is needed to develop and test other approaches based on an understanding of climate change effects in a multi-pressure context. One possibility is the establishment of a subscript value to an EQR[35] to quantify the decrease in EQR estimated as attributable to climate change. For example, a reported EQR of $\mathbf{0.55_{0.10}}$ would indicate that established assessment systems have assigned an EQR of **0.55** (moderate status) but the subscript of **0.10** indicates that climate change is responsible for a decline of 0.10 (from 0.65 to 0.55) resulting in a change from good to moderate status. Essentially this would be conceptually similar to temperature anomaly maps where deviation from the established normal conditions is reported.

Such a system could be applied by MS to their waterbodies where the EQR is being modified by climate change. Supporting information regarding the climate extremes experienced by a site can be taken from annual European State of the Climate reports that provide data and maps on temperature anomaly, soil moisture deficit, river discharge and associated documents on heatwaves and floods. However, **attributing a portion of an EQR decline to climate change will be a key scientific challenge**. Approaches could include model development or more simple comparisons with years

[35] Ecological Quality Ratio (EQR) incorporates the key WFD requirements for ecological classification: typology, reference conditions, and class boundary setting.

where the climate was more representative of normal conditions (for example identified from published maps of monthly temperature anomaly).
Further work is needed, including how to manage objectives and Programmes of Measures in this context – would the component of the EQR attributable to climate change be subject to additional measures if feasible (e.g. reducing nutrients further) or could it be used to allocate or manage exemptions/derogations? Several benefits are also apparent:

i. Maintains original EQR (for time-series analysis)
ii. Makes transparent the MS estimate of how CC is influencing the waterbody
iii. There should be broad consistency for regions/types, allowing us to understand how CC is affecting aquatic ecology across Europe.

In some respects, the WFD is already complex and adding another layer is regrettable. However if MS seek to modify their objectives by citing the effect of climate change, the presentation of two pieces of evidence for the waterbody is inevitable: 1) evidence of deteriorating climate and 2) an estimation of how much of the status decline is due to climate change and no other factors.

13 ANNEX III: ROLE OF THE SEA AND EIA PROCESS IN CLIMATE CHANGE ADAPTATION

A Strategic Environmental Assessment (SEA) is a systematic process for evaluating the environmental implications of a proposed policy, plan or programme and provides means for looking at cumulative effects and appropriately addressing them at the earliest stage of decision-making alongside economic and social considerations. The SEA assesses the extent to which a given policy, plan or programme:

- provides an adequate response to environmental and climate change-related challenges;
- may adversely affect the environment and climate resilience, and
- offers opportunities to enhance the state of the environment and contribute to climate-resilient and low-carbon development.

Ideally, a SEA should be integrated into the policy, plan or programme preparation process from its early stages and the Government must have a high degree of ownership. Public participation is also essential for a successful SEA.

In 2013 the EC developed guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment to improve the consideration of these issues across the EU MSs.

The Environmental Impact Assessment (EIA) Directive requires MSs to ensure that projects likely to have significant effects on the environment because of their nature, size or location are subject to an assessment of their environmental effects. This assessment should take place before development consent is given, i.e. before the authority/ies decides (s) that the developer can go ahead with the project.

The Directive harmonises EIA principles by introducing minimum requirements, in particular for the types of projects that should be assessed, the main obligations of developers, the assessment's content and provisions on the participation of competent authorities and the public.

The Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment aims to help MSs improve how climate change and biodiversity are integrated in EIAs carried out across the EU.

In cases where structural measures such as dams or weirs are needed to mitigate droughts and floods Art 4.7. WFD might be applied. In such a case the links between WFD, EIA and SEA should be considered. The relevance and potentials for synergies and streamlining of assessments required under the EIA and Article 4(7) are specified in more detail in Guidance No. 36 - Article 4(7) exemptions to the environmental objectives (see in particular chapter 4.2 and Annex A).

14 GLOSSARY

Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. This glossary entry builds from definitions used in previous IPCC reports and the Millennium Ecosystem Assessment.

Aridity: The state of a long-term climatic feature characterised by low average precipitation or available water in a region. Aridity generally arises from widespread persistent atmospheric subsidence or anticyclonic conditions, and from more localised subsidence in the lee side of mountains.

Climate Change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land-use.

Cost–benefit analysis: Monetary assessment of all negative and positive impacts associated with a given action. Cost–benefit analysis enables the comparison of different interventions, investments or strategies and reveals how a given investment or policy effort pays off for a particular person, company or country. Cost–benefit analyses representing society's point of view are important for climate change decision-making, but there are difficulties in aggregating costs and benefits across different actors and across timescales.

Drought: Drought is a natural phenomenon. It is a temporary, negative and severe deviation along a significant time period and over a large region from average precipitation values (a rainfall deficit), which might lead to meteorological, agricultural, hydrological and socioeconomic drought, depending on its severity and duration.

Ecological Flows: Ecological flows (often abbreviated as e-flows) are considered within the context of the WFD as "a hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies as mentioned in Article 4(1)". Considering Article 4(1) WFD, the environmental objectives refer to: (a) non deterioration of the existing status (b) achievement of good ecological status in a natural surface water body, (c) compliance with standards and objectives for protected areas, including the ones designated for the protection of habitats and species where the maintenance or improvement of the status of water is an important factor for their protection, including relevant Natura 2000 sites designated under the Birds and Habitats Directives (BHD). Where water bodies can be designated as heavily modified water bodies and/or qualify for an exemption, related requirements in terms of flow regime are to be derived taking into account technical feasibility and socio-economic impacts on the use that would be impacted by the implementation of ecological flows. The flow to be implemented in these water bodies is not covered by the working definition of ecological flows and it will be named distinctively.

Ecosystem services: Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.

Emission scenario: A plausible representation of the future development of emissions of substances that are radiatively active (e.g., GHGs, aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy and land use) and their key relationships. Concentration scenarios, derived from emissions scenarios, are often used as input to a climate model to compute climate projections.

Extreme weather event: An event that is rare at a particular place and time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10^{th} or 90^{th} percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense.

Flood: The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.

Forecasts: Prediction (with included uncertainty/error) of the future based on the current conditions and past events, factors and trends.

Governance: A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing and monitoring policies and measures. Whereas government is defined strictly in terms of the nation-state, the more inclusive concept of governance recognises the contributions of various levels of government (global, international, regional, sub-national and local) and the contributing roles of the private sector, of nongovernmental actors, and civil society to addressing the many types of issues facing the global community.

Hazard: The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Maladaptation: Actions that may lead to an increased risk of adverse climate-related outcomes, including via increased GHG emissions, increased vulnerability to climate change, or diminished welfare, now or in the future. Maladaptation is usually an unintended consequence.

Mitigation (of climate change): A human intervention to reduce emissions or enhance the sinks of greenhouse gases. Note that this encompasses carbon dioxide removal (CDR) options.

Mitigation measures: In climate policy, mitigation measures are technologies, processes or practices that contribute to mitigation, for example, renewable energy technologies, waste minimisation processes, public transport commuting practices.

Monitoring and evaluation: Monitoring and evaluation refers to mechanisms put in place at national to local scales to respectively monitor and evaluate efforts to reduce GHG and/or adapt to the impacts of climate change with the aim of systematically identifying, characterising and assessing progress over time.

Projections: Potential future evolution of a quantity or set of quantities characterising the earth system, often computed with the aid of a model. Unlike predictions, projections are not initialised with current climate conditions but rely on observed forcing (e.g. in terms of emissions) and on scenarios of future socio-economic and technological developments that may or may not be realised.

Resilience: The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.

Risk Reduction: Three components of risk (hazard, exposure, vulnerability) must be described in terms that are sector, location, and dynamic specific (Harm, Wolters, Timboe, & Metthews, 2022). Adaptation can reduce the risk by addressing one or more of the three risk factors. The reduction of vulnerability, exposure, and/or hazard potential can be achieved through different policies and actions over time until limits to adaptation are reached.

Scenarios: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.

Water abstraction: Water is removed from any sources, either permanently or temporarily. Mine water and drainage are included. Similar to water withdrawal.

Water body: Any mass of water having definite hydrological, physical, chemical and biological characteristics and which can be employed for one or several purposes.

Water demand: Water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning.

Water pollution: Presence in water of harmful and objectionable material - obtained from sewers, industrial wastes and rainwater run-off - in sufficient concentrations to make it unfit for use.

Water resources: Distinction is made between renewable and non-renewable water resources. Non-renewable water resources are not replenished at all or for a very long time by nature. This includes the so-called fossil waters. Renewable water resources are rechargeable due to the hydrological cycle unless they are overexploited, comprising groundwater aquifers and surface water like rivers and lakes. Internal renewable water resources comprise the average annual flow of rivers and groundwater generated from endogenous precipitation.

Water reuse: Reclaimed water can be indirectly reused when it is discharged into a watercourse, diluted and used again downstream. Direct reuse means the direct supply of reclaimed water from the reclamation facility to the user. It also can apply to the recharge of an aquifer.

Water scarcity: Water scarcity is a man-made phenomenon. It is a recurrent imbalance that arises from an overuse of water resources, caused by consumption being significantly higher than the natural renewable availability. Water scarcity can be aggravated by water pollution (reducing the suitability for different water uses), and during drought episodes.

Water stress: Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.).

Water supply: Water supply refers to the share of water abstraction which is supplied to users (excluding losses in storage, conveyance and distribution).

Water use: Three types of water use are distinguished: (i) withdrawal, where water is taken from a river, or surface or underground reservoir, and after use returned to a natural water body, e.g. water used for cooling in industrial processes. Such return flows are particularly important for downstream users in the case of water taken from rivers; (ii) consumptive, which starts with withdrawal but in this case without any return, e.g. irrigation, steam escaping into the atmosphere, water contained in final products, i.e. it is no longer available directly for subsequent uses; (iii) non-withdrawal, i.e. the in situ use of a water body for navigation (including the floating of logs by the lumber industry), fishing, recreation, effluent disposal and hydroelectric power generation.

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