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Flood risks and environmental vulnerability

Exploring the synergies between floodplain restoration, water policies and thematic policies

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Acronyms and abbreviations

APSFR	Areas of Potential Significant Flood Risk
CAP	Common Agricultural Policy
CLC	Corine Land Cover
DPSIR	Driving forces, Pressures, States, Impacts, Responses
DRR	Disaster Risk Reduction
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EM-DAT	Emergency Events Database from the Centre for Research on the Epidemiology of Disasters (CRED)
ETC/CCA	European Topic Centre on Climate Change impacts, vulnerability and Adaptation
ETC/ICM	European Topic Centre on Inland, Coastal and Marine water
EU	European Union
EUSF	European Union Solidarity Fund
FHRM	Flood Hazard and Risk Map
FRMP	Flood Risk Management Plan
ha	hectares
JRC	Joint Research Centre
MAES	Mapping and Assessment of Ecosystems and their Services
MFF	Multiannual Financial Framework
NBMW	Nature, biodiversity, marine and water (policies)
NUTS	Nomenclature of Territorial Units for Statistics
NWRM	Natural Water Retention Measure
OECD	Organisation for Economic Co-operation and Development
PFRA	Preliminary Flood Risk Assessment
PWS	Payment for Watershed Services
RBD	River basin district
RBMP	River Basin Management Plan
RDP	Rural Development Programmes
SEA	Strategic Environmental Assessment
SRES	Special Report on Emissions Scenarios
UoM	Unit of management
WFD	Water Framework Directive

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European Topic Centre on Inland, Coastal and Marine waters (ETC/ICM) is an international consortium brought together to support the European Environment Agency (EEA) in its mission to deliver timely, targeted, relevant and reliable information to policy-makers and the public for the development and implementation of sound environmental policies in the European Union and other EEA member countries. Since 1 January 2014 the Helmholtz Centre for Environmental Research — UFZ is leading ETC/ICM with a consortium of 17 partners.

European Topic Centre on Climate Change impacts, vulnerability and Adaptation (ETC/CCA) is an international consortium contracted by the European Environment Agency (EEA) to carry out specific tasks in the area of climate change impacts, vulnerability and adaptation across Europe. The 2014–2018 ETC/CCA consortium is made up of 14 partner organisations, led by the Italian Euro-Mediterranean Center on Climate Change (CMCC).

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Executive summary

Nowadays floodplain areas are reduced in size or no longer function as active floodplains, thereby impacting on the delivery of environmental services to local and regional communities and economies. These services include regulating services such as protection against floods or water purification; provisioning services, such as nutrient collection and fertile soil formation; and cultural services, such as recreational, tourism and educational services; transport routes; and finally a secure water supply.

Many of Europe's natural floodplains are under pressure: besides land use changes, there are limitations in exactly how water is flowing and where to, reduced storage capacity, water quality and pollution issues, as well as a reduction in the natural support to lower flood waves. What remains of floodplains can be viewed as important for nature conservation and will play a part in the aim to restore at least 15 % of degraded ecosystems and their services by 2020 under the targets of the EU Biodiversity Strategy.

Since 2012, a new source of information became available for the European Environment Agency (EEA) following the assessment and mapping of floods in Europe for the 'Directive on the assessment and management of flood risks', better known as the 'Floods Directive'. The EEA's 'Flood risks and environmental vulnerability' report provides an overview of floods since 1980 and the related social, economic and environmental impacts. This report improves the knowledge base on the subject as a European flood impact database had not existed prior to the publication of the EEA report. The report combines the information from the Floods Directive, mainly from the preliminary flood risk assessments, with information from global databases, as well as an analysis of a questionnaire completed by national authorities. The result is a more complete overview of significant floods events and impacts.

The need for data on the impact of flooding

An essential element of the Floods Directive is the combined reporting on environmental, economic and social issues. While many detailed local and national inventories of previous floods and their impacts are available, quantitative information on flood impacts is scarce and hardly comparable on a European scale. Environmental impacts are underrepresented in global databases on floods or natural hazards.

Meanwhile, significant differences remain in the way countries report on previous flood events. The next reporting cycle for the Floods Directive (2016–2021) could benefit from additional guidance in order to obtain more homogeneous information on the impacts of past flood events across Europe. Through the Floods Directive it is expected that for future flood events more information on the environmental impacts (both negative and positive) will become available. Data sources, such as the applications for major floods in the European Solidarity Fund, can further improve the database on past floods in Europe.

Significant data gaps remain on the European scale, such as on floodplain delineation, land use in floodplains, or the economic benefits from ecosystem services. However, the knowledge currently available allows progress to continue on the implementation of sustainable flood risk management practices, including building synergies with other relevant environmental legislation such as the Water Framework Directive and the Birds and Habitats directives.

Floodplain management and restoration

Floodplain management and restoration does not only focus on reducing flood risk but also on promoting environmental, societal and economic benefits. Sustainable flood risk management combines elements to:

- reduce the exposure to flooding;
- lessen the vulnerability of people and property;
- execute a sensible management of land and the environment;
- improve preparedness and early warning for adverse events.

Dikes, dams and other human-engineered solutions are examples of infrastructures that continue to prevent and protect many former floodplains from flooding. Meanwhile, green infrastructure, a network of natural and semi-natural areas designed and managed to deliver a wide range of ecosystems services, also assists flood protection. Floodplain restoration is an important measure which gives more room to rivers, develops ecological beneficial hydrological regimes and enhances floodplain and wetland habitats.

There are many examples where 'hard' infrastructure can be adapted to make better use of the natural habitat and of the landscape ecology. Even when human developments that need to be protected against flooding make it (almost) impossible to go back to a complete natural state, natural water retention measures (NWRMs) can contribute to reduced flood risk, less soil erosion or water purification and nutrient recycling. To manage floodplains and to assist in the restoration of wetlands and alluvial areas by promoting NWRMs, synergies between different policy fields have to be explored.

Synergies in water, nature and sectoral policies

In 2012 the European Commission published 'A Blueprint to Safeguard Europe's Water Resources' (the Water Blueprint) to tackle the obstacles which hamper action to improve the status of EU waters. Synergies between managing flood risk, reaching or maintaining a good ecological status, and safeguarding the nature or ecosystem services in floodplains can be very complex. Some form of prioritisation needs to take place at least on the level of river basin management planning. Interactions along rivers need to be taken into account, as well as targets such as the 15 % restoration of degraded ecosystems by 2020 from the Biodiversity Strategy.

To recognise the synergies between water and nature policies, the aims and working methods of the Floods Directive should also be taken into account when developing actions for the Water Framework Directive (WFD) and the Birds and Habitats directives. Although the WFD does contribute to mitigating the effects of floods; managing and reducing flood risk is not one of its principal objectives. The restoration of healthy ecosystems, e.g. through the Natura 2000 networks, is often a very effective way of preventing and mitigating floods. 'Green' flood prevention measures, through the restoration of floodplains, are also beneficial. Currently, synergies between water and nature policies are underexploited as well as the links to the Common Agricultural Policy (CAP). Early cooperation, negotiation and flexibility can avoid any crossover work between the various programmes emanating from the different directives.

The EEA's 'Flood risks and environmental vulnerability' report, together with the recent EEA report on 'Water-retention potential of Europe's forests', are among the publications the EEA will make on synergies between policies. Reports are also planned to come out in the 2017–2018 period on the synergies between floods, climate change adaptation and disaster risk reduction; and on the synergies between the WFD and environmental policies, including floods.

Climate change and land use planning

Over time, climate change and adaptation have become more prominent in water and nature policies. In the Water Blueprint, climate change, together with land use and economic activities, are depicted as having a negative impact on Europe's water status. Climate change adaptation and building resilience to disasters are key activities for sustainable water management. River basin and flood risk management, as well as reporting obligations from the Birds and Habitats directives, are updated once every six years. New knowledge on climate change and adaptation can therefore be built into these plans.

Extreme floods (and droughts) are likely to be the biggest challenge for adaptation and likely to be the cost drivers for adapting the infrastructure. While strategies for flood risk management require locally adapted measures, including sustainable land management and spatial planning, using a river basin management approach — congruent with ecosystem-based management principles — avoids passing on negative consequences further downstream.

Financing and governance

Measures that work with natural processes, such as the maintenance or restoration of floodplains, have a multitude of benefits. An ecosystem services approach is important which would highlight any benefits and makes the cost effectiveness of these measures more explicit.

Most of the nature-based solutions for flood risk management are related to the prevention of and protection against flooding. In addition, the Floods Directive also focusses on preparedness measures such as flood forecasting and warning. While many of them are financed from national funds, the EU LIFE programme is an important financial instrument to support environmental, nature conservation and climate action projects, such as NWRMs. Other sources to prevent flood damage based on natural processes are the EU's rural development programmes or the Cohesion Funds.

Financial instruments also need to be in place for response during and recovery after a flood event, such as insurance mechanisms or the EU Solidarity Fund. Unfortunately due to the need to make decisions quickly little attention is paid to ecosystem services during periods of response and recovery.

The better the coordination across the various levels of planning and management, the more attention can go to reduce vulnerability and integrated measures which will be sustainable over the long term. Combining efforts on the WFD and the Floods Directive may prove to be beneficial. However, these processes can only be driven at the European level and yet need to be implemented at the river basin level.

Successes in nature, water and marine policies invariably depend on progress across various sectors. A coordinated implementation of the WFD, the Marine Strategy Framework Directive, the Birds and Habitats Directives, the Biodiversity 2020 strategy and the Floods Directive would help achieve a higher quality environment by using integrated solutions and, through coherent measures and actions, enhance the effectiveness of the policies. As the objectives of water and nature legislation do not contradict themselves no obvious obstacles should exist for efficient collaboration, as shown by many examples across Europe, some of which are presented in this report.

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1 Introduction

In 2012, the European Commission (EC) published 'A blueprint to safeguard Europe's water resources' (EC, 2012d) to tackle the obstacles that hamper action to further improve the status of European Union (EU) waters. The EEA's state of water reports ([1]) made an important contribution to the argument that water-quality and quantity need concerted action. There are numerous challenges to be faced in attaining the objectives of the Water Framework Directive (WFD) (EU, 2000, Art. 4), and floods, inundations, modifications of the water flow and morphological changes are among the many pressures affecting Europe's water bodies.

Whereas the report 'Water resources in Europe in the context of vulnerability' (EEA, 2012d) focused on droughts, water scarcity and floods, this report focuses on flooding, the role of floodplains and the impact of hydromorphological alterations on the ecosystem services that floodplains provide. The aim is to support the implementation of the EU Floods Directive (EU, 2007), in particular with regard to environmental impacts. To do this, it is necessary to investigate EU water and nature policies as well as thematic policies affecting floodplains to identify synergies and approaches to capitalise on them. The report assesses the pressures affecting floodplains as well as the wider driving forces that have an overall influence on catchment areas, such as climate change.

In 2016–2018, the EEA will prepare a series of updates on the state of EU waters based on the information that becomes available from the second generation of River Basin Management Plans (RBMPs). The updates will include flood impacts and flood risk management. The principal information on flood impacts and flood risk management at EU level is based on the reporting under the Floods Directive, which contains information on past and potential future floods, the Flood Hazard and Risk Maps (FHRMs) and the draft Flood Risk Management Plans (FRMPs).

The first objective of this report is to provide a conceptual assessment of how existing information can be used to provide a more comprehensive assessment of the quantitative and qualitative status of Europe's water resources and the ecosystem services that they provide. Although we do not suggest that the information is complete and taking account of changes still being implemented in the FRMPs, the information allows us to make suggestions for an improved second implementation cycle of the Floods Directive in terms of information structure and environmental objectives. It also enables us to develop a better understanding of freshwater ecosystem services, and of the environmental impact of flooding and flood-protection measures. Therefore, Natural Water Retention Measures (NWRMs), Green Infrastructures and other measures that work with natural processes are explored in more detail in Chapter 2.

The second objective is to explore the synergies between the Floods Directive and other water and nature directives and the most relevant sectoral legislation. In particular, the WFD (EU, 2000) and the Birds and Habitats Directives (EU, 1992, 2010) are of interest in the framework of streamlining environmental requirements as expressed in the Biodiversity 2020 Strategy (EC, 2011a) and the potential revision of the WFD after 2018. Notwithstanding the similarities in content and process between the Floods Directive, the WFD and the Birds and Habitats Directives, there are also important differences between them. Whereas the WFD and the Birds and Habitats Directives are mainly environment-related legislation (although with some overlaps with economic and social issues), an essential element of the Floods Directive is its combination of environmental, economic and social issues (Evers and Nyberg, 2013). Human health, the environment, cultural heritage and economic activities are the four impact categories that EU Member States are required to report on for the Floods Directive and it is feasible and desirable to reduce the risk of adverse consequences in these areas. Where the WFD contributes to mitigating the effects of floods, assessing, managing and reducing flood risk is not one of the principal objectives of the directive, and it does not take into account any future changes in flood risk as a result of climate change.

([1]) See http://www.eea.europa.eu/themes/water/water-assessments-2012, accessed 13 November 2015.

The third objective of this report is to identify and share good practice to improve the Preliminary Flood Risk Assessment (PFRA) in the next cycle of implementation of the Floods Directive in 2018. The second cycle will begin soon after the reporting of the FRMPs, which will complete the first cycle of implementation with its reporting in March 2016. Although many details about floods and their impacts are known at a local level, it remains difficult to get a detailed European overview. The Floods Directive collects information on significant past floods as part of the PFRA (EU, 2007, Art. 4). To be of most value for European-wide assessments, the structured information provided needs to be detailed enough to create added value beyond some descriptive terms such as 'extreme event' or 'large impact' but at the same time be general enough to be comparable. Although this is achieved to a certain extent in the 2011 PFRA, an analysis of the information (e.g. ETC/ICM, 2013) shows that more can be done in this regard.

This report limits itself mainly to the environmental aspects related to floods and flood-protection measures. Economic, health and cultural impacts will not be dealt with in detail, although their consideration is necessary for integrated (flood) risk management. And, notwithstanding the fact that coastal water bodies are covered by the WFD and coastal flooding by the Floods Directive, this report primarily focuses on rivers, river floodplains and fluvial flooding.

Target audience for this report

The main audience in mind when writing this report are flood risk managers involved in the FRMPs and the programmes of measures. On account of budget restrictions, and with water and land being scarce resources, searching for synergies with other water and nature protection communities and creating integrated visions and measures is an (perhaps even *the*) effective and efficient way forward. Although it may seem that working in isolation results in quicker action (at least initially), collaborative working ultimately enables greater progress.

The report is also meant as an introduction for water managers involved in the RBMPs and for people involved in nature conservation and restoration to better understand how their actions can contribute to sustainable flood risk management. Given the importance of land use changes and developments such as urbanisation as significant pressures, spatial planners and developers will find information on synergies and the sustainable development of floodplains. In general, this report provides examples for all those interested in how water management (and, more specifically, flood risk management) based on an ecosystem services approach is shaped and how flood risk management is linked to a wide variety of thematic polices influencing and influenced by flood risk management.

1.1 Floods in Europe

Flooding is a natural and not uncommon process associated with river dynamics, but across Europe and throughout the ages, floods have affected human health ([2]), the environment, cultural heritage and economic activities. The floods in Ireland and the United Kingdom from April 2012 onwards were caused by a series of weather events that lasted through the winter of 2013. Central Europe was hit by extreme floods in May and June 2013, affecting both the Elbe and Danube river catchments. In many locations, these floods caused the highest water levels and/or discharges ever recorded (BfG, 2013; Gierk, 2013; ICPDR, 2014). Although the damage was still significant, the measures taken for example in Austria and Germany after the 2002 floods proved to be highly effective (Neuhold, 2013).

In May 2014, a low-pressure cyclone affected a large area of south-east and central Europe, causing floods and landslides (e.g. along the River Sava). Serbia and Bosnia and Herzegovina suffered the greatest damage. In Serbia alone, there were over 50 fatalities, roughly 32 000 people were evacuated and over 1.5 million people were affected (Pavlović, 2014). Kundzewicz edited a book with many detailed national and regional perspectives on floods in Europe (Kundzewicz, 2012) and Chorynski and colleagues provide an overview of large floods in Europe in the 20th century (Chorynski et al., 2012).

After a flood event, different data typically circulate on the damage caused and the numbers of people affected. However, a consistent database of the impacts of past floods is not available for Europe (EEA, 2011b). Overviews of flooding and its impacts on a European scale have been extracted from global disaster databases. Nevertheless, information on past flood events is the basis for a sound understanding of flood-generating processes across Europe and for reliable predictions of future flood changes. Therefore, the development of a comprehensive, publicly available, database of flood events and their impacts in Europe is desirable (EEA, 2011b).

([2]) Including social impacts to individuals or the community.

Based on the information on past floods reported by EU Member States in the PFRA under the Floods Directive (EU, 2007, Art. 4) and complemented by data from global databases such as the Emergency Events Database (EM-DAT) from the Centre for Research on the Epidemiology of Disasters (CRED) (EM-DAT, 2015) or Dartmouth Flood Observatory (Brakenridge, 2015), an EU overview of significant floods and their impact is now available for the 39 EEA member countries and cooperating countries

European Flood Impact Database

A European Flood Impact Database has not been available so far. In most European countries, national databases for natural hazards are available but they are very different in terms of the types of hazards included, information on impacts, thresholds to include events, availability of the detailed data, etc. (ETC/CCA, 2013a, 2013b). The amount of information available increased significantly after the reporting of the PFRA (mainly on flood impacts, although these were often not quantified or expressed in monetary terms) and the information was better structured owing to the template imposed by the Floods Directive reporting schemas.

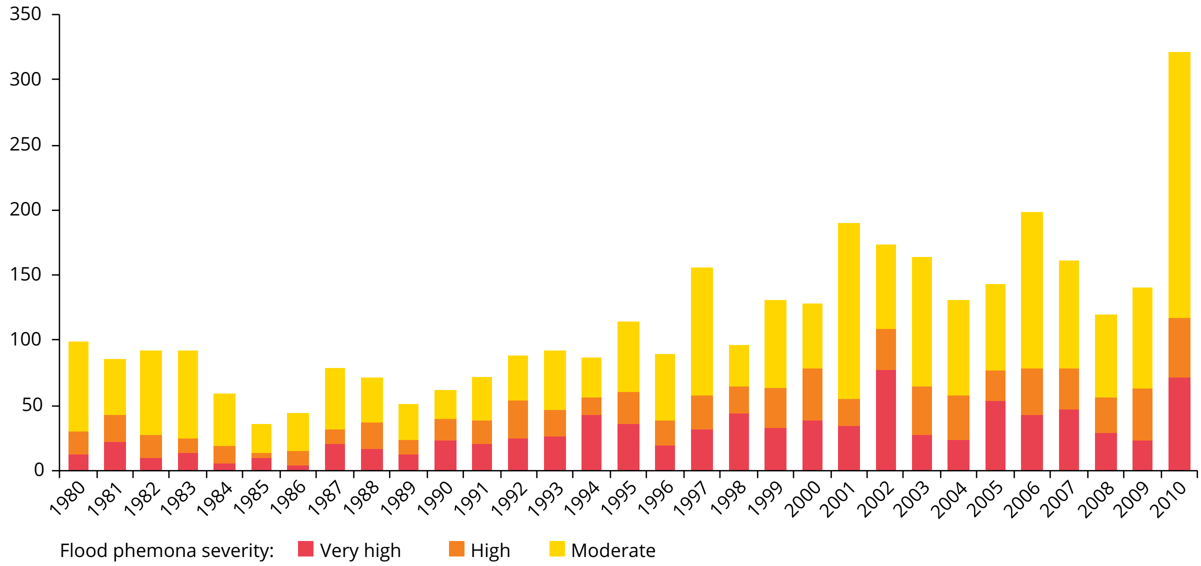
Nevertheless, the PFRA reporting in itself is insufficient to function as the single database on European floods and flood impacts (ETC/ICM, 2013). In addition, floods are not restricted by administrative boundaries and, for example, no information was available on non-EU European countries.

Using the information on past floods reported by EU Member States and combining that information with available data from global data sets on floods and additions by national authorities on a voluntary basis has already provided a more complete overview of European floods since 1980. A country consultation for corrections and additions ran from February to May 2015. The resulting database, which includes environmental impacts and impacts on cultural heritage where available, as well as fatalities and economic damage, is available at http://www.eea.europa.eu/data-and-maps/data/european-past-floods (accessed 13 November 2015).

Between 1980 and 2010, 3 563 distinct flood phenomena (floods) were evidenced in 37 European countries ([3]). As Figure 1.1 shows, the highest number of floods is reported for 2010 (321 floods), when 27 countries were affected. This number is associated with the 'central European floods', which occurred across several

Figure 1.1 Reported flood phenomena between 1980 and 2010

Number of reported flood phenomena between 1980 and 2010 (EEA-39)



Note: Flood severity is an assessment of flood phenomena magnitude. It considers the reported values on frequency, reported total damage (in Euros and descriptive classes), number of flood events within one flood phenomena unit and severity classes as reported in the Dartmouth Flood Observatory database (ETC/ICM, 2015b). All phenomena with fatalities are in the 'very high' severity class.

Source: http://www.eea.europa.eu/data-and-maps/data/european-past-floods, accessed 13 November 2015.

([3]) All EEA member and cooperating countries (see http://www.eea.europa.eu/about-us/countries-and-eionet, accessed 13 November 2015), except for Liechtenstein and Malta.

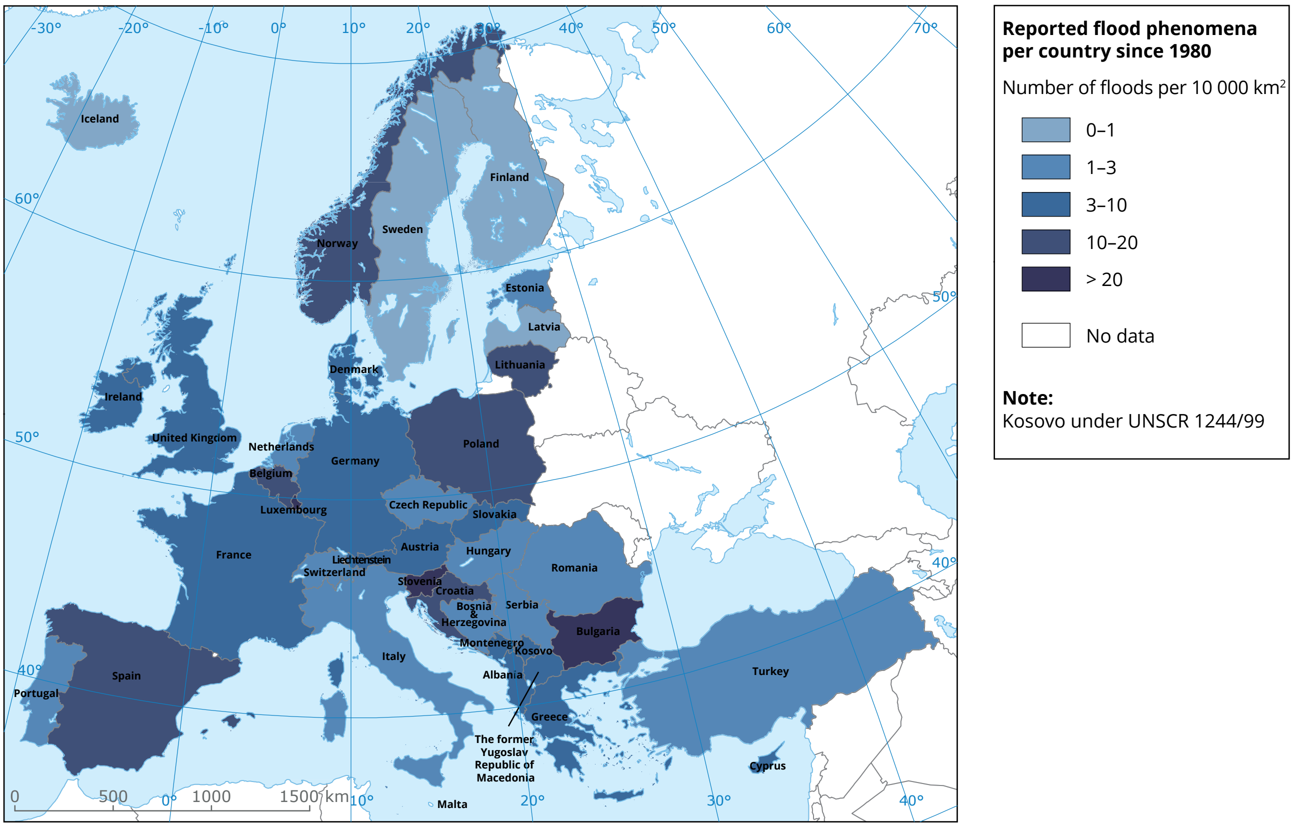
central European countries during May and June 2010. In Poland, more than 20 people lost their lives, approximately 3 400 km^2 of land was inundated by the floods and the total cost of flood damage has been assessed as more than EUR 2 billion (2 000 million). Bulgaria, France, Germany, Hungary, Serbia, Slovakia and other countries were affected (ETC/ICM, 2015b). The apparent increase in the number of reported floods has not been cross-checked with the natural flooding of the rivers. Therefore, based on Figure 1.1, no conclusions can yet be made about trends or patterns of flooding in Europe because, besides the length of time series, a reporting bias (EEA, 2015a) means that the method of reporting across Europe is not homogeneous. The EEA will further improve knowledge on past floods and their impacts, including trend analyses for European regions. Map 1.1 shows the number of reported flood phenomena since 1980, which are weighted in respect of country areas.

1.2 Environmental aspects of floods and floodplains

Water-quantity management, including extremes such as floods or hydrological droughts, should always be considered together with their impacts on environmental quality and water-quality management. As mentioned in the 'Blueprint to safeguard Europe's water resources' (EC, 2012d) water over-abstraction is the second most common reported pressure in the first generation of RBMPs. At the same time, the hydrological regime defines the physical habitat in and along water bodies. The flow requirements required to reach a good ecological status therefore go beyond minimum discharges during dry periods but have to take into account the full range of discharges, from base flows (including low flows) to flood regimes with different magnitudes, frequency, duration, etc. This link between quantity and quality is clearly made in the guidance document on ecological flows in the implementation of the WFD (EC, 2015d). The objectives on protection and conservation of freshwater-dependent ecosystems can be reached only when discharges and water levels vary over weeks, months and years. This is because these ecosystems usually need varied intra- and inter-annual flows to remain functionally intact.

Consequently, it is possible that flow requirements for the conservation of certain species or habitats go beyond those to reach 'Good Ecological Status' and therefore should be considered in the implementation of the WFD (EC, 2015d). In this context, it is useful to consider the

Map 1.1 Reported flood phenomena (number of floods per 10 000 km^2) per country (since 1980)



fact that, in many cases, these ecosystems do not need high flows in every year. For example, floodplain forests require only occasional flood events for their continued regeneration, and this gives considerable flexibility to long-term water-quantity management for these forested ecosystems in which environmental flows are used as a water-quantity management approach (Hughes et al., 2008).

Where a flood, according to the definition in the Floods Directive (EU, 2007, Art. 2 (1)), is 'the temporary covering by water of land not normally covered by water', the main area of interest is the floodplain in which this flood happens. The natural floodplain can be defined in different ways (see Section 1.3) and four key questions define the role that this area can have in mitigating or reducing flood risk:

- How is the area used? What are the potential consequences of flooding?
- What is the hydrological regime?
- What is the connectivity of the water body (river) and the floodplain?
- What is the water-quality?

Many former natural floodplains are currently under pressure from urbanisation, infrastructural developments and agriculture. In order to reduce the negative economic and human impacts of floods, protection or regulation measures have been implemented along many rivers. These have the negative side effect that the amount of water that can be stored is limited. Owing to soil sealing or soil compaction, the water-retention capacity to reduce the amount of overland flow is reduced as well.

However, the impact of soil sealing is certainly not limited to the floodplain itself, as it is even more relevant at the scale of the catchment, where it affects the river hydrology. Both the peak flows that cause floods and the low flows that occur in dry periods are becoming more extreme, with a higher variation in water levels over time. We also have to question the degree to which the water level is managed within narrow boundaries to support navigation, hydropower or other economic activities. These issues have to be considered with regard to the hydrological regime close to the environmental flow, which will have variations over time, including periods of low flows and floods.

Reduced connectivity between river beds, river channels and floodplains is often related to flood-protection. Dykes, dams and other infrastructural measures prevent water from entering a protected area, unless a major flood event happens and the infrastructure is overtopped or fails. Because flood-protection provides increased security, the areas behind a flood-protection infrastructure are often highly developed, which has considerable economic and social consequences if the flood event is of a higher magnitude than the protection level. In addition, these protection measures may have a strong negative impact on the environmental quality of the water body and the floodplain, limiting the potential of the area to provide ecosystem services. A natural floodplain provides a wide range of services, which people can rely on directly, including water flow regulation, water-retention or habitat for wildlife and recreation, and which are limited when the connectivity between water body and floodplain is hampered by permanent infrastructures.

A final issue is water-quality and pollution. This takes account of both the quality of the water entering the floodplain and the pollution that occurs as a result of contaminated inert soils brought in suspension or of the flooding of polluting installations (industries, but also oil and septic tanks). In Chapter 2 we look in more detail at these different aspects and at how natural floodplains can provide several ecosystem services that help to improve water-quality.

1.3 Floodplain areas

Although the Floods Directive (EU, 2007, Art. 2) defines a 'flood' as the temporary covering by water of land not normally covered by water, a 'floodplain' is not defined in this directive. Water management and flood risk management do not apply to only the riverbed or the lake area, which are covered with water all year round. They include the whole catchment, from the area from which raindrops flow into a river, lake or reservoir. Land cover patterns in the catchment, soil, topography, etc. are some of the parameters defining how much and how quickly rain ends in the river or lakes within the catchment.

The floodplain is the area that is irregularly but more or less frequently covered with water in times of high water discharges in its adjacent rivers. Despite several individual case studies, there is no comprehensive classification of floodplains (Nanson and Croke, 1992). The genetic floodplain, that is, the alluvial landform adjacent to a river and built of its sediments, differs from the hydraulic floodplain, which is the area inundated with a certain frequency regardless of land use, soil, etc. In this report, we use the term 'floodplain' to describe intermittently inundated lands next to river beds and channels (Matella and Jagt, 2014). First, we give an overview of terms closely related to 'floodplains', before, second, discussing the status, functions and trends relating to floodplains in Chapter 2.

Photo: © André Künzelmann/UFZ

1.3.1 Alluvial areas

Floodplains in alluvial areas are the low-lying areas along a river, which are characterised by the alternation of floods and low water, and which are built of sediments deposited during overflow and lateral migration of the streams. As part of the river landscape, floodplains are in a permanent state of exchange with the river and its catchment area (Gautier et al., 2009). Water sources are primarily from the lateral overspill of river water; however, high groundwater levels can also contribute to floodplain inundation (Tockner and Stanford, 2002). The water flow in floodplains is multidimensional. Upstream–downstream interactions constitute the longitudinal dimension. The lateral dimension includes interactions between the river bed or river channel and the riparian floodplain areas, whereas the vertical dimension encompasses exchanges with the groundwater aquifer. The fourth dimension (i.e. time) provides the temporal scale (Ward, 1989). The soil of alluvial areas consists of sands, silts, clays or gravels and is called fluviosoils, whereas floodplains with organic soils are not understood as being alluvial areas.

Flow variations, together with different sediment deposition patterns, create patches with different levels of connectivity to the stream and soil features. The heterogeneous and quickly changing habitats, together with natural fertilisation caused by suspended matter and nutrients introduced by flooding, lead to the high biodiversity and productivity in floodplains (Craft and Casey, 2000; Naiman and Décamps, 1997; Robinson et al., 2002).

1.3.2 Riparian zones

Riparian zones are transitional areas at the interplay of land and freshwater ecosystems, with distinctive soil, hydrology and biotic conditions, which are strongly influenced by the streamflow, as typical characteristics (Naiman et al., 2005). In this way, riparian zones refer not only to floodplains and wetlands, but also include uplands where a direct water–land interaction is important. For more details about concept and definitions, see Clerici et al. (2011). Mountainous areas show a high portion of natural riparian zones, although their presence is lower in the main European plains where the landscape is characterised by agricultural use (Clerici et al., 2011). The EC Joint Research Centre (JRC) developed a zonation tool for riparian zones, which, although not designed as a high-precision mapping tool, provides a European overview, which is a key requirement of the European Green Infrastructure (Clerici et al., 2011; EC, 2013d). The high-resolution delineation of riparian zones is actually done as part of the Copernicus Land Monitoring Services ([4]) and will support the objectives of several European legal acts and policy initiatives, such as the EU Biodiversity Strategy to 2020 (EC, 2011a), the HBDs (EU, 1992, 2010) and the WFD (EU, 2000).

1.3.3 Wetlands

Wetland is a very general term (with many different definitions) that refers to areas such as marshes, swamps, bogs, fens, mangroves, etc., all of which have in common periodic inundation or prolonged waterlogging which creates suitable conditions for aquatic life (Tiner, 2013). A view closer to the definition of the hydraulic floodplain (see Section 1.3.4) includes a basis for the frequency and duration of flooding required for an ecological effect. Wetland has been defined as 'land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophyte vegetation and various kinds of biological activity which are adapted to a wet environment' (National Wetlands Working Group, 1997). The ecological effects do not need to be changes in the vegetation but could include aspects such as reduced redox potential that have consequences for biogeochemical cycles.

The Ramsar Convention (UNESCO, 1994) uses a very broad definition whereby wetlands include 'all lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peatlands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fish ponds, rice paddies, reservoirs and salt pans' (Ramsar Convention Secretariat, 2014). In total, 42 different wetland types are distinguished in the Ramsar multinational classification system: 12 types of marine and coastal wetlands, 20 inland wetland types and 10 man-made types of wetland (Ramsar Convention Secretariat, 2013). Floodplains are not listed as a specific type of wetland, but overlap partly or in full with several wetland types.

According to one wetlands inventory, there are > 37 million hectares (ha) of wetlands in EEA member and cooperating countries (Stevenson and Frazier, 1999a, 1999b). Over one-third (12.8 million ha) is attributed to Sweden; and Estonia, Finland and Norway were all assessed as having > 3 million ha each. Other countries with extensive wetland areas (all > 1 million ha) in this study are Denmark, France, Germany, Poland, Turkey and the United Kingdom. It is clear that the means of measuring the extent of wetland areas across Europe are not very precise: not only are data missing for many countries, but the methodologies to delineate wetlands would also benefit from the inclusion of seasonal and inter-annual climate variations and anthropogenic influences as well as the elimination of variations potentially introduced by the investigator (Kriegner et al., 2015). This becomes clear when the detailed Swedish wetland survey is considered, which has identified 9.3 million ha of wetlands, representing 23 % of the land area of the country, of which mires count for 5.2 million ha. Of the mires, 3.7 million ha are non-forested bogs, whereas 1.4 million ha are forested (Gunnarsson and Löfroth, 2014; Statistics Sweden, 2013).

In Corine Land Cover (CLC) (EC and EEA, 1995), wetlands are mapped with different codes for inland wetlands and coastal wetlands. Inland wetlands are further divided into inland marshes (defined as 'Low-lying land usually flooded in winter and more or less saturated by water all year round') and peatbogs (defined as 'Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited'). Coastal wetlands were further split into coastal marshes, salines and intertidal flats. In 2000, 114 217 km^2 were mapped as wetland, of which 110 987 km^2 were inland wetlands. In 2006, this increased to 119 021 km^2 and 115 537 km^2, respectively, and further increased in 2012, when 131 022 km^2 and 127 458 km^2 were mapped as total wetland areas and inland wetlands, respectively ([5]).

As part of the Copernicus Land Services, a high-resolution layer for wetlands is currently under development. Based on remote sensing, it aims to provide a more homogeneous overview of Europe's wetlands, but the results are not yet validated (Copernicus Land Monitoring Services, 2015; Langanke, 2013).

1.3.4 Hydraulic floodplains

The hydraulic floodplain delineates an area that has a certain statistical probability of flooding. Mapping of these floodplains is based on evidence

([4]) See http://land.copernicus.eu/local/riparian-zones accessed 13 November 2015.
([5]) Calculation based on CLC data for 34 European countries (data for Greece, Spain and Turkey could not been included into the analysis owing to data gaps).

from historic events and/or hydraulic modelling. Different methodological choices, including but not limited to extreme value statistics, equations for flow computations in the river bed or channel and the adjacent floodplain, the accuracy and precision of a digital elevation model, the inclusion of flood defences or not, etc., make the detailed results for most (if not all) EU Member States difficult to compare or to join into a European map.

A global overview of river flood extents is publicly available on the PREVIEW Global Data Platform ([6]) (Herold and Mouton, 2011). The JRC makes European flood maps based on simulation with the LISFLOOD model (Rojas et al., 2012, 2013) for eight different return periods between 2 and 500 years. Although these results have value for European-wide studies on climate change impacts, the river-routing network does not include the plentiful small tributaries.

Remaining floodplains on the European scale correspond roughly to the Floods Directive reporting categories of flood hazard and risk areas with a high or medium probability of flooding, being a likely yearly probability of 1 % or less. Former floodplains are usually disconnected from the flood dynamic by dyke constructions. Often, the groundwater table in these areas is still connected to the river dynamics and during floods seepage water can occur.

In the Floods Directive (EU, 2007, Art. 6) flood hazard maps for different scenarios have to be produced where the medium probability scenario for all mapped floods in the FHRM is the 100-year return period flood event. This does not mean that these maps can easily be merged to get one fully homogeneous flood hazard map for Europe, but, at least for those countries where data were available, they give the most detailed overview available so far. All the above confirms that there is no single data set suitable to answer all questions and that many data sets are still under development and need improvement.

1.4 Strategic flood risk management

Strategic flood risk management can be described as a section of the wider integrated water management and planning approach for river basins and coastal areas. It focuses on reducing flood risks and promoting environmental, societal and economic opportunities both at present and in the longer term (Sayers et al., 2015). The concept of risk management is under constant evolution, in particular in adopting an adaptive approach, which works with natural processes, relies on ecosystem services in a positive way and is part of an integrated water management approach (Sayers et al., 2013; WMO, 2009). Despite having received attention in academia and at local scale, a focus on the beneficial relationship between floods and ecosystem services at planning level is a rather recent development (Sayers et al., 2015).

Large flood events have an impact on thinking, policy and practices in flood risk management. The river floods of 1947 and the devastating coastal floods of 1953 in the Netherlands, Belgium and the United Kingdom, raised issues of food security and the need for clear roles and responsibilities in flood risk management together with a boost in increased performance of warning systems. The large river floods that occurred over several years during the 1990s paved the way for basin-wide flood risk management and a larger role for non-structural measures in addition to structural ones ([7]) and an increased awareness for the role of spatial planning (e.g. in Room for the River and related policies and practices). In the first decade of the 21st century, Europe suffered major damaging floods, including the catastrophic floods along the Danube and Elbe rivers in the summer of 2002. Severe floods in 2005 further reinforced the need for concerted action. In 2006, the EC proposed a directive on the assessment and management of flood risks, which was published in the Official Journal on 6 November 2007 and which is known as the Floods Directive (EU, 2007).

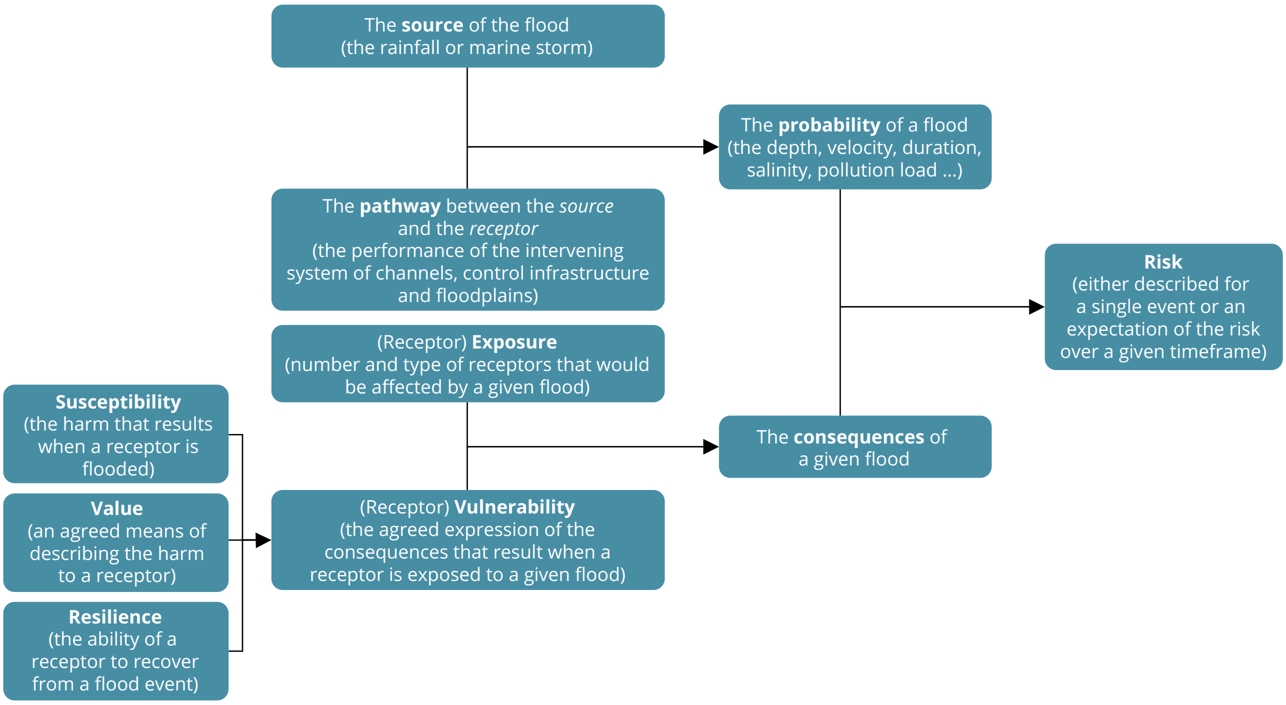
The review process for the 2007 floods in the United Kingdom (Pitt, 2008) clearly indicates the need to consider all sources of flooding and their combined occurrence as well as the need for detailed spatial information. It is probably too early to define how the recent floods (see Section 1.2) in central Europe and the Balkans have shaped and changed our thinking on flood risk management.

To understand flood risk, one has to understand its different components and their interrelationships to make informed decisions (Figure 1.2). Not all areas of flood risk are discussed in this report: topics such as the protection of critical infrastructure or vital societal functions are extremely relevant and important for integrated risk management but are outside the scope of this report.

Flood risk management, like the management of natural hazards in general, is one of the elements

([6]) See http://preview.grid.unep.ch, accessed 13 November 2015.
([7]) For definitions, see Pichler et al., 2009.

Figure 1.2 The components of risk



Note: This is one possible visualisation of the components of risk and other models including more, fewer or different components exist as well.

Source: Sayers et al., 2015.

supporting the broad aims of sustainable development (UNISDR, 2015) as clearly stated in the Sendai Framework for Disaster Risk Reduction 2015–2030 (UN, 2015). A strategic flood risk management approach that supports sustainability is, therefore, in contrast to the still widespread misconception, much more than maintaining the integrity of flood control structures now and in the long term (Sayers et al., 2015). Such an approach includes maintaining, restoring and strengthening the long-term health of all associated ecosystems, societies and economies by promoting the following key principles (Sayers et al., 2015):

- efficiency and fairness: maximising the utility of an investment while ensuring a process that also protects the most vulnerable members of society and including consistent non-structural strategies that are available to all;
- resilience and adaptive capacity: purposeful approaches to strategy development and design that are inherently risk-based and that actively manage uncertainty. These strategies rely upon creativity and innovation in:
  - selecting responses that do not rule out future options;
  - being effective under a wide set of plausible future scenarios;
  - observing changes and reassessing scenarios of possible futures;
  - modifying policies, strategies and structure plans appropriately;
- safeguarding ecosystem services: soft-path measures (e.g. land use changes or wetland restoration) and selective hard-path measures (e.g. bypass channels or controlled storage) both offer opportunities to simultaneously manage flood risk and rely on ecosystem services simultaneously.

There can be trade-offs between safeguarding ecosystem services and safeguarding nature, and synergies between managing flood risk, promoting ecosystem services and safeguarding nature can be very complex and require some form of spatial prioritisation or the prioritisation of the services to be promoted.

The synergies between different types of measures, even between different types of infrastructural measures, are often overlooked, and concepts such as working with natural processes or NWRMs need to be part of the core toolkit of every flood risk manager.

The flood risk manager (and water manager) cannot do this alone, as a wide range of EU policies influence the intersections between flood risk management, flood vulnerability and environmental impacts in a significant way (see Chapter 4). These are not only environmental policies, such as the WFD and the Birds and Habitat Directives, but also policies on agriculture, pollution or risk prevention, assessment and management. Although there are many examples of improved quality in Europe's environment (EEA, 2015g), including Europe's waters (EEA, 2015b), there is still room for improvement through better implementation of policies and public participation, with active involvement rather than simple information supply or consultation. There are many good examples of active involvement from which to draw lessons (EEA, 2014e), although, in general, there is a lack of data really tailored to purpose (see also Section 4.2.4).

Where many environmental problems that require concerted action (because of their global or cross-border nature, or because they can be handled more efficiently and transparently on EU level) benefit from EU policies, there is a gap to bridge in cross-boundary goal setting for specific issues (IEEP, 2013), including flood risk management, and in the implementation of the existing policies (EC, 2012d). As Chapter 4 further clarifies, synergies between water (WFD, Floods Directive) and nature legislation (Birds and Habitats Directives) is underexploited, a conclusion that can be repeated for synergies between water legislation and thematic policies such as the rural development regulation (EU, 2013c) of the Common Agricultural Policy (CAP).

Policies and their implementation are complemented by practices. For several EU countries, the Floods Directive coming into force did not radically change all existing practices, some of which have existed for decades or longer. Other practices get renewed or new attention. A flood risk management approach focusing on reducing fatalities and the number of affected people is an example of a common practice, whereas mapping environmental vulnerability is (at country level) is new for most countries. The same is true for NWRMs or measures working with natural processes (EC, 2014a): some measures will sound very familiar to flood managers, whereas others will be new in some regions of Europe or are used but without fully exploiting the synergies with water and nature goals.

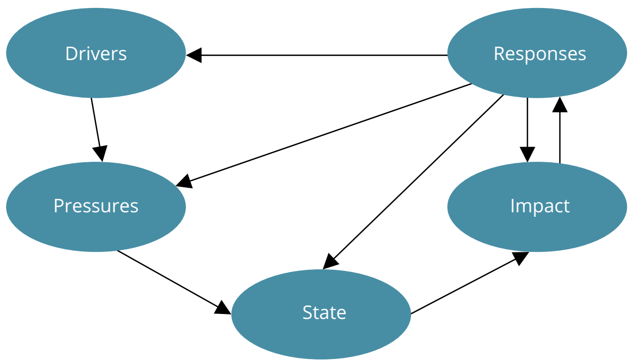
1.5 Outline and reading guidance

This chapter of the report sets the scene, with a condensed overview of floods and their environmental impacts in Europe. Many terms are used as synonyms or approximations of floodplains, so we briefly describe the most relevant ones, as well as the data availability on a European scale. The introduction ends with a brief description of strategic flood risk management as part of a wider integrated water management as an introduction to the policy developments and synergies between water, nature and sectoral policies in Chapter 4.

The following chapters can be linked to different elements in the DPSIR (driving forces, pressures, state, impact and response) framework (see Figure 1.3), which describes interactions between the environment and society. This report does not describe all the sources, mechanisms and characteristics of flooding, but focuses on fluvial events. The report also does not describe all consequences of flooding, but rather focuses on environmental consequences and on flood-protection measures. When looking at the impact data available for previous floods in Europe (Box 1.1), much was unknown and the same gap was felt in assessing these impacts.

Chapter 2 first describes the state of floodplains, where they are and what their environmental quality is. Based on the spatial data available in the reporting for the Floods Directive, no full European overview could be made, but how that could be done in future and what lessons can be learned is shown for those countries for which information was available at the end of 2015. The second part of Chapter 2 focuses on the pressures affecting the status of floodplains. However, these pressures can be understood only when the

Figure 1.3 The DPSIR framework for reporting on environmental issues



Source: Stanners et al., 2007.

Box 1.1 Green and grey infrastructure

There are many definitions of green infrastructure, as summarised in EEA (2011a). In the Communication on 'Green Infrastructure — Enhancing Europe's Natural Capital' (EC, 2013d), green infrastructure is described as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings.'

Grey infrastructure can be described as 'manmade improvements that support and improve human settlement such as roads, power lines, water systems, schools and hospitals' (EEA, 2011a), and is regularly understood as the human-engineered solutions that often involve concrete and steel, such as dykes and dams.

The French National Strategy for Flood Management, for example, sees the preservation of existing green infrastructure as a top priority, whereas new grey infrastructure is listed as the last option when all other possibilities are considered insufficient (General Directorate for Risk Prevention and Ministry of Ecology, Sustainable Development and Energy, 2014).

However, in practice, there are many cases in which infrastructure works can be adapted to make better use of the environmental features and maintain or improve the potential of an area to deliver that wide range of ecosystem services, also described as 'greening the grey'. At a recent workshop, it was concluded that it is not about the number or size of infrastructure, but about the outcome and the ecosystem functions maintained (EEA and ETC/ICM, 2015).

In 2016, the EEA will publish a report on green infrastructure as a tool for flood-protection and climate change adaptation, as well as on the cost-efficiency aspects of green infrastructure.

main drivers are known (Chapter 3). Driving forces are the socio-economic (and cultural) forces originating from human activities, which increase (or mitigate) pressures on the environment. Driving forces usually have a broad scope, influencing not only what happens in floodplains but also what happens in the socio-economic environment in a wide sense (i.e. affecting the whole catchment) or an even wider sense (i.e. climate change, on a regional, continental and global scale).

The responses directly affecting the state of floodplains by protecting or restoring them are described at the end of Chapter 2. Policy developments and the implementation of policies are responses to influence the driving forces and decrease the pressures affecting floodplains and are the core of Chapter 4.

It is not only the Floods Directive that influences the management of floods and floodplains, and Chapter 4 looks at the links between the Floods Directive, the WFD and the nature directives. Wider thematic policies, such as agriculture, hydropower or navigation, have potential conflicts with the maintenance or restoration of a natural floodplain, but synergies and management options with mutual benefits can also be found.

The second part of Chapter 4 takes a wider approach, looking at cross-cutting issues such as how climate change and adaptation are dealt with in water and nature policies and how they (can) support nature-based solutions for floodplain management. The role of spatial planning is also considered. Two complex issues are the financing of integrated measures, which are beneficial for flood risk management, river restoration and sectoral benefits, and governance and participation structures.

Chapter 4 ends with an inventory of the knowledge gaps that still exist, with regard to available data and methods, as well as the policy integration gaps between those policies affecting the same area, namely the floodplain.

In Chapter 5 we bring together our observations on data availability and the creation of a European database on past floods based on the reporting during the first implementation cycle (2009–2015) of the Floods Directive. We summarise the importance of NWRMs.

The screening of the water, nature and sectoral policies showed many links in terms of both processes and the measures used to implement the policies. The options that are available to make more use of these synergies, while working with natural processes and not ignoring the inherent uncertainties discussed in detail in Chapter 4, are summarised. Chapter 5 ends with guiding principles for the next steps in flood risk management and the implementation of the Floods Directive.

2 Status of Europe's floodplains

Europe's floodplains once covered wide stretches along the European rivers and had high ecological importance. Cleared for agriculture and completely changed through urban expansion and flood control structures, only fractions of floodplains remain. Despite limited homogeneous spatial data on the extension and quality of Europe's remaining floodplains, there are clear examples that ecological importance is not only dependent on the land use in the floodplain area and the water-quality, but also on the hydrological regime and the connectivity between the water body and the floodplain.

Some of the largest and best-preserved floodplains in Europe are found along the Danube, Sava, Drava and Morava rivers in Austria, Croatia, Hungary, Slovakia and Slovenia (Klimo and Hager, 2001; Lazowski and Schwarz, 2014; Mölder and Schneider, 2010; Španjol et al., 1999). One of the last morphologically intact river corridors in the Alps is the River Tagliamento in Italy (Bertoldi et al., 2009; Tockner et al., 2003), and the Allier and Durance rivers in France are examples of morphologically intact river sections with a high connectivity to the surrounding floodplains.

2.1 Ecological importance of floodplains

Floodplains have an important role in flood risk management, by modifying the river discharge and protecting societies and economic activities from damage. Floodplains are also very heterogeneous habitats that create favourable conditions for many species and thus have a high environmental value.

2.1.1 Floodplain water bodies

Under natural conditions, floodplains can contain a wide range of freshwater ecosystems, including permanently flowing and temporal channels, oxbow lakes, spring brooks, tributaries and temporary wetlands. They are found along a gradient of decreasing hydrological connectivity from permanent to temporary links with the main bed of the river (Paillex et al., 2007). The degree of hydrological connectivity influences major habitat components such as the water's physicochemical properties, its nutrient content, substrata and morphology, which are the main drivers of biodiversity in floodplain freshwater ecosystems (Amoros and Bornette, 2002). For example, studies of fish communities have underlined the importance of diverse water bodies in riverine landscapes for spawning and as nurseries, feeding and refuge areas (Aarts et al., 2004), which can also support the resettlement of the river after extreme disturbances.

2.1.2 Floodplain forests

The natural vegetation of floodplains in most European areas except the far north is dense riverside forest (Glaeser and Wulf, 2009; Klimo and Hager, 2001). Only a few areas, such as open water, flood channels, silted up areas and gravel banks, are naturally non-wooded. Floodplain forests occur on nutrient-rich soils, which have, over time, been deposited by rivers during flooding. They are among the richest, most complex, forest ecosystems of Europe but vary considerably in structure and in the species present in different biogeographical regions of Europe (Girel et al., 2003).

Rapidly growing softwoods such as willows and poplars are characteristic of floodplains near rivers with soil largely comprising sediment. They depend on newly deposited sediments and well-timed floods for their natural regeneration by seed, and the absence of these conditions across most European floodplains has resulted in some species, such as black poplar, becoming rare (Hughes et al., 2008). Floodplain areas further away from rivers tend to have a lower water table and older soil and, therefore, are often made up of hardwood tree species such as oak, ash or elm, but they also contain a high diversity of other tree species. Whereas softwood forests can experience between 60 and 180 inundation days annually, hardwood floodplain forests can be flooded between 1 and 60 days per year in the growing season. Because of their nutrient-rich soils, a good water supply and diversely structured forest strata, old hardwood forests host some of the most species-rich and unique plant, bird or invertebrate communities of European forests (Scholz et al., 2005). Natural floodplain forest in Scandinavia often grows on nutrient-poor organic soils (peat) and is dominated by pine, spruce, birch and willow.

2.1.3 Floodplain grasslands

For centuries, many floodplains have been used extensively for livestock feeding. Population growth and increased knowledge of flood-protection led to more intensive grazing and farming activities on floodplains during the Middle Ages. Forests became more and more degraded as they were replaced by productive farmland and open extensive grassland. These man-made grasslands are characteristic of seasonally flooded areas and are characterised by a high diversity of grass and herbaceous species and by regular management (EC, 2008; Leyer, 2004). Such grasslands have small-scale relief features, including hollows and lower and higher areas with different flood-return frequencies and different groundwater levels. Although floodplain grasslands cover most of the active floodplains in western, central and eastern Europe, most of them are threatened by hydrological alterations, intensified and changing agricultural needs and changing policies (EC, 2008; EEA, 2015f). Grasslands on peat soils are common man-made vegetation for floodplains in Scandinavia but also in northern parts of central Europe with very specific and rare vegetation types.

These floodplain water bodies, forests and grasslands have several corresponding Habitats Directive Annex-1 habitat types (EU, 1992) which are the natural habitat types of community interest whose conservation requires the designation of special areas of conservation.

2.2 Status of Europe's floodplains: remaining areas and environmental quality

When assessing the status of Europe's floodplains, it is important to look not only at the location and remaining areas of floodplains, but also at their functionality and the potential of the area to deliver different ecosystem services as well.

2.2.1 Ecosystem services to describe environmental quality

Ecosystem services can be defined as the contributions that ecosystems make to human well-being. They are seen (Table 2.1) as arising from the interaction of biotic and abiotic processes (Haines-Young and Potschin, 2013). Most ecosystem services refer specifically to the 'final' outputs from ecosystems, providing benefits for humans and society (Maes et al., 2012). Ecosystems and socio-economic systems can be linked through flows of ecosystem services and through the drivers of change that affect ecosystems either as a consequence of using the services or as direct impacts attributable to human activities (Figure 2.1). Ecosystems are shaped by the interactions of biotic and abiotic environment. Ecosystem functions are the capacity or potential to deliver ecosystem services, where ecosystem services are the realised flow (EC, 2013g).

As one of the most important ecosystem services of floodplains, flood regulation supply addresses the capacity of the ecosystem to decrease flood hazards by reducing run-off (Millennium Ecosystem Assessment, 2005). For the ES flood regulation, there is a spatial link between the downstream areas of a river catchment that mainly benefit from increased flood-protection and the headwaters and upstream areas that comprise the flood regulation supplying areas (Syrbe and Walz, 2012).

Optimising the supply of multiple ecosystem services can be done by Green Infrastructure, (EC, 2013d), an interconnected network of green areas for the conservation of ecosystem functions, which provides benefits to society (Schindler et al., 2014). The concept is also linked to the Habitats Directive (EU, 1992, Art. 10), with the aim of overcoming landscape fragmentation, and to the Biodiversity strategy (EC, 2011a), which aims to maintain and enhance ecosystems and their services by 2020 by 'establishing green infrastructure and restoring at least 15 % of degraded ecosystems'. The importance of investing in ecosystems, including floodplains as a particular area of interest, is also recognised as a source of economic development for the regional and cohesion policy of the EU (EC, 2011b).

To estimate the effect of protecting and restoring floodplains, one needs an overview of the different ecosystem services and their quantity provided by that area. On the European level, this exercise is ongoing for all terrestrial and marine ecosystems ([8]) in the Mapping and Assessment of Ecosystems and their Services (MAES) process (EC, 2013g, 2014e) (see also Box 2.5).

([8]) See http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/draft-ecosystem-map-europe, accessed 16 November 2015. Floodplains are not a type of ecosystem but overlap and can be part of almost all ecosystem types and subtypes. In the freshwater pilot, (inland) wetlands were included but these overlap only partly with floodplains (see Section 1.3).

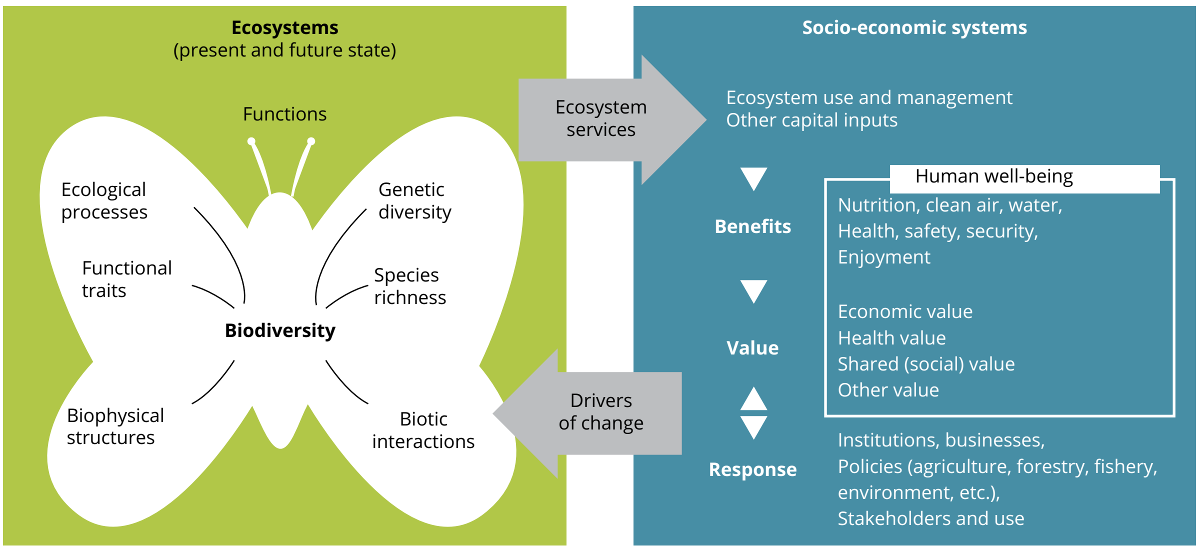
Table 2.1 Definitions of eocsystem services used in the Common International Classificiation of Ecosystem Services

Provisioning services	Includes all material and biota-dependent energy outputs from ecosystems; they are tangible things that can be exchanged or traded, as well as consumed or used directly by people in manufacturing. Within the provisioning service section, three major divisions of services are recognised: • nutrition, including all ecosystem outputs that are used directly or indirectly as foodstuffs (including potable water); • materials (biotic) that are used directly or employed in the manufacture of goods; and • energy (biomass), which refers to biotic renewable energy sources and mechanical energy provided by animals. Provisioning of water is attributed either to nutrition (drinking) or to materials (industrial, etc.). It is considered an ecosystem service because its amount and quality is at least partly steered by ecosystem functioning. For this reason, seawater is not included.
Regulating and maintenance services	Includes all the ways in which ecosystems control or modify biotic or abiotic parameters that define the environment of people (i.e. all aspects of the 'ambient' environment). These ecosystem outputs are not consumed but affect the performances of individuals, communities and populations and their activities. Within the regulating and maintenance section, three major service divisions are recognised: • mediation of waste, toxic substances and other nuisances: the services that biota or ecosystems provide to detoxify or simply dilute substances, mainly as a result of human action; • mediation of flows (air, liquid, solid masses): this covers services such as regulation and maintenance of land and snow masses, flood and storm protection; and • maintenance of physical, chemical, biological conditions: this recognises that ecosystems provide for sustainable living conditions, including soil formation, climate regulation, pest and disease control, pollination and the nursery functions that habitats have in the support of provisioning services.
Cultural services	Includes all the non-material ecosystem outputs that have symbolic, cultural or intellectual significance. Within the cultural service section, two major divisions of services are recognised: • physical and intellectual interactions with biota, ecosystems and land-/seascapes; and • spiritual, symbolic and other interactions with biota, ecosystems and land-/seascapes.

Note: Revised version of the Common International Classification of Ecosystem Services (CICES) version 4.3; see http://cices.eu accessed 13 November 2015.

Source: EC, 2013g (based on Haines-Young and Potschin, 2013).

Figure 2.1 Conceptual framework for ecosystem assessments



Source: EC, 2013g and EEA, 2015e.

In a study on the Somerset Levels and Moors wetlands (Acreman et al., 2011), the different ecosystem services are assessed individually before being combined, as the real added value in terms of management of the area is in the synergies or conflicts between the ecosystem services. Besides mapping the ecosystem services, the different ecosystem services also need to be assessed to value their importance by means of indicators (EC, 2014e). This assessment is site-specific and, for example, in the Somerset Levels and Moors wetlands case, most ecosystem services are based on the area being wet, with the exceptions of flood storage and methane emissions (Acreman et al., 2011). The active involvement of an area for flood risk protection needs to consider this, and leads to trade-offs between different land-management practices. In addition, climate change may make it difficult to maintain actual or preferred conditions (Acreman et al., 2009) and the example demonstrates that not all services can be maximised simultaneously (Willems et al., 2012).

2.2.2 Today's floodplains in Europe

In Europe, up to 90 % of the former riparian floodplains have been lost during the past centuries or are no longer functionally intact (Tockner et al., 2009; Tockner and Stanford, 2002). In addition, only about 10 % of the original European floodplain forest remains, mostly in the larger river systems of eastern Europe. In recognition of this, they have been placed on Annex 1 of the Habitats Directive (EU, 1992) where they are collectively referred to as 'Alluvial Forests' (Hughes et al., 2012). The main reason for the loss of active floodplains is the continued decline in floodplain areas. This is as a result of flood-protection measures to prevent land uses from flooding that are not compatible with inundations (such as agriculture or urban expansion), or infrastructure for hydropower development or maintenance of shipping channels (see Section 2.3).

For example, in Germany, a national inventory accounted for 70–90 % of floodplain area loss along 10 000 km of 79 larger rivers and the streams of eight river basins (BMU and BfN, 2009; Brunotte et al., 2009). For the larger rivers, the loss accounts for approximately 90 % of the 15 000 km² there once was, and, in general, only 1–2 % of the active floodplain is currently covered with near-nature floodplain forest (Brunotte et al., 2009). For the different river sections of the River Danube, the floodplain area loss varies between 73 % and 95 %, whereas the Danube delta lost only around 30 % (Schneider, 2010; Schneider et al., 2009). When including river tributaries, the floodplain loss can be estimated at 80 % (Table 2.2).

Table 2.2 Examples of floodplain area loss along large rivers in Europe

River section	Morphological floodplain area (km²)	Remaining floodplain area (km²)	Loss of floodplain area (%)
Upper Danube (Austria, Germany) ([a,b])	1 762	95	95
Central Danube (Croatia, Hungary, Serbia, Slovakia) ([a])	8 161	2 002	75
Lower Danube (Bulgaria, Republic of Moldova, Romania, Serbia) ([a])	8 173	2 193	73
Danube Delta (Romania, Ukraine) ([a])	5 402	3 799	30
Tisza (Hungary, Romania, Ukraine) ([c])	36 000	1 800	95
Upper Rhine (France, Germany) ([d])			93
River Rhine (Austria, Switzerland, France, Germany, Netherlands) ([d])	8 000	1 200	85
River Rhine (Germany) ([b])	2 064	454	80
Rhine and Meuse (Netherlands) ([e])			90–100
Seine (France) ([f])			99
Oder (Germany, Poland) ([g])	3 593	970	73
Oder (only Germany) ([b])	941	94	90
Middle Ebro River (Spain) ([h])			58

Sources: ([a]) Schneider et al. (2009); ([b]) Brunotte et al. (2009); ([c]) Haraszthy (2001); ([d]) Schmid-Breton (2015); ([e]) Rijkswaterstaat Waterdienst (2008); ([f]) Tockner et al. (2009); ([g]) WWF Germany (2000); ([h]) Ollero (2010).

Whereas the German floodplain inventory (Box 2.1) contains information on remaining and former floodplains of larger rivers, the Austrian (Lazowski and Schwarz, 2014) and Swiss (Hausammann et al., 2005) inventories focus on the remaining high-value areas. The latter contains a multitude of spatial, hydromorphological, habitat and management information, including threats and pressures on the selected floodplain areas.

The remaining floodplains in Europe are very often far from being functionally intact and are affected by a multitude of hydraulic measures or separated from the riverbed by summer levees. Despite these alterations, the fragments of remaining floodplains are important areas for nature conservation: > 30 % of all riparian zones mapped by the JRC are protected under EU law (Clerici et al., 2013) (i.e. are part of the Natura 2000 network) ([9]).

At the European scale, no floodplain inventory or systematic assessment of floodplain status has so far been made. Floodplain loss and assessment of its quality is not registered or reported in a consistent way within the EU. With new spatial data reported under the European Floods Directive (EU, 2007), combined with CLC data, as well as information reported under the Habitats Directive (EU, 1992), potentially new overviews will be possible but these will still have limitations (see Box 2.2).

Box 2.1 German floodplain inventory and assessment

The first nation-wide, consistent and updatable inventory of the loss and quality status of German floodplains provides an efficient overview of the position, dimension and status of floodplains at larger rivers in Germany (Brunotte et al., 2009). The survey of the floodplain areas was conducted for sections of the rivers with a catchment area of at least 1 000 km², and tidal waters were not included. The geomorphological floodplain, consisting of the remaining active and former floodplains, which is defined in this case as the area that could be inundated if there were no man-made dykes, was assessed. For each 1-km section of the rivers, the active and former floodplain areas were mapped separately for the left and the right sides of the rivers, and land use cover in seven classes, as well as nature conservation value and protection status, were documented.

Based on a standardised approach (Koenzen, 2005) to define reference conditions for riverine landscapes (their potential natural status), the status of all mapped floodplains was assessed. Main input data for this assessment comprise the principal factors of habitat quality for all species, including the geomorphological and hydrological habitat conditions, and land use.

The floodplain assessment methodology refers to a reference status (which is close to being unaffected by human intervention) and the results are presented in five classes, which give the degree of modification compared with the potentially natural status (Table 2.3). Despite similarities in approach, these are not the same as the five classes used to evaluate status for the Water Framework Directive (EU, 2000) and both may not be mixed.

Floodplains of larger rivers in the past covered about 15 000 km², which corresponds to 4.4 % of the German territory. Two-thirds of the morphological floodplain was lost by embanking. At large parts of rivers such as the Rhine, Elbe, Danube and Oder only 10–20 % of the former floodplains can still be inundated. More than one-third of the remaining active floodplains are intensively used as arable land (28 %) or urban (6 %) areas, and < 10 % of the active floodplains perform their full ecological functions. The remaining near-natural hardwood forests of floodplains cover only about 1 % of the active floodplain area. Compared with the potential natural status, < 1 % of the assessed active floodplain sections are classified as 'nearly natural' (see Figure 2.2), whereas 54 % of the floodplain sections are assessed as 'severely modified' or 'totally modified'. On the one hand, this situation has resulted from the intense agricultural use on fertile soils of floodplains and, on the other hand, from the former importance of rivers as waterways for transport and trade, as well as rising urbanisation.

As expected, the areas that are severely modified and totally modified are more abundant (79 %) in the former floodplains than in active floodplains (54 %). However, there is a small percentage (4 %) of 'slightly modified' former floodplain sections, which apparently still maintain a 'floodplain-like' environment without being inundated for a longer period. Therefore, these areas should be targeted for a potential restoration (activation) of former floodplains.

Source: BMU and BfN, 2009; see http://www.geodienste.bfn.de/flussauen accessed 13 November 2015.

([9]) See http://ec.europa.eu/environment/nature/natura2000/ for details, accessed 13 November 2015.

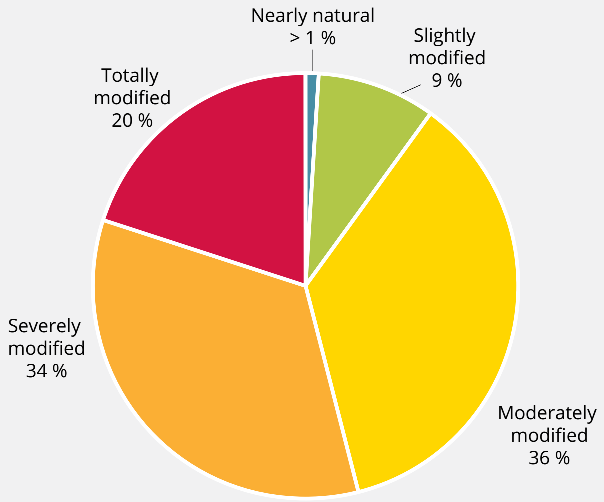
Box 2.1 German floodplain inventory and assessment (cont.)

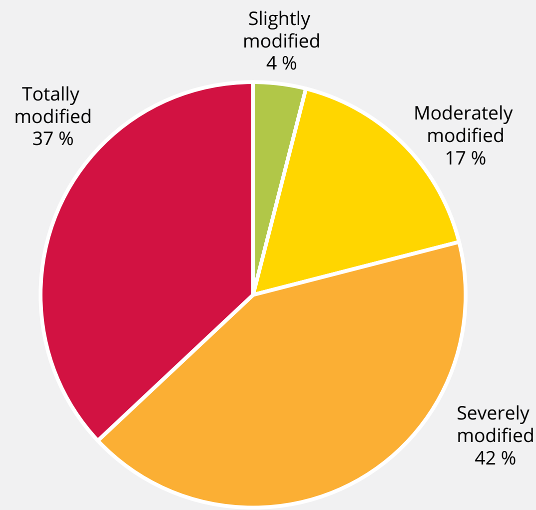
Table 2.3 The five classes of floodplain status with a condensed specification

Class		Specification
1	**Nearly natural**	Floodplains not, or to a very small degree, disconnected from floods by river regulation and/or flood-protection measures Rivers only slightly regulated, with high possibility of flooding Mainly no, or very low-intensity, land use, mostly forest, wetlands and, rarely, grassland
2	**Slightly modified**	Floodplains to a small degree disconnected from floods by river development and/or flood-protection measures Rivers variably regulated, but usually with high possibility of flooding Mainly low-intensity land use, mostly forest, wetlands and grassland
3	**Moderately modified**	Floodplains partly disconnected from floods by river development and/or flood-protection measures Rivers generally regulated, but usually with possibility of flooding Variable intensity of land use
4	**Severely modified**	Floodplains widely disconnected from floods by river development and/or flood-protection measures Rivers generally regulated, partly dammed High-intensity land use, mainly intensive agriculture and urban areas
5	**Totally modified**	Floodplains completely disconnected from floods by river development and/or flood-protection measures Rivers generally regulated heavily, frequently dammed High-intensity land use, mostly with high percentage of urban areas

Source: Brunotte et al., 2009.

Figure 2.2 Comparison of the distribution of the active and former floodplain status classes in Germany





Note: Comparison of all assessed sections of active floodplains (left) with former floodplain areas (right).

Source: Based on Brunotte et al., 2009 and BMU and BfN, 2009.

Box 2.2 Distribution of floodplain areas

To get an overview of where active floodplains still occur, reported Flood Hazard and Risk Maps (FHRMs) (EU, 2007, Art. 6) are used as proxies. Although they were made for all EU countries, the data of the medium probability flood hazard maps, all with a likely return period of 100 years ([a]), were available for only nine countries (see Table 2.4) ([b]). Overall, floodplain areas in these nine countries cover around 5 % of the total area of these countries, with significant differences from country to country. It should be noted that, even for the countries for which data are available, FHRMs are made only for these areas selected as Areas of Potential Significant Flood Risk (APSFR) and not for floodplains along all rivers. In addition, APSFR are mostly defined for these areas with negative consequences from flooding rather than the active floodplains and retention areas upstream or downstream of the settled area selected. The information presented in Table 2.4 is illustrative, although not representative, of the distribution of floodplains in Europe.

The nine countries (Table 2.4) with spatial information available on flooded areas consist of 4 029 subcatchments (catchments with fourth Straler order CCM2/WS04 (JRC, 2008)) with an average area of 383 km². Higher floodplain coverage (see Map 2.1) is significant for the subcatchment for the Italian Reno, Arno, Po rivers, the Croatian parts of the Sava and Drava rivers, the River Tisza in Hungary, the River Elbe in northern Germany and the River Danube in eastern Romania.

Land uses in floodplains

An intersection of the medium scenario flood hazard maps with the land use types (CLC 2012 version) is shown in Figure 2.3. The 15 land use types are aggregated from the CLC types on levels 2 and 3 (EC and EEA, 1995), providing most detail on forest, semi-natural areas and wetland and being more aggregated for artificial surfaces. More than 40 % of the floodplains are used for arable farming, most of which is almost exclusively (over 97 %) non-irrigated. The highest absolute coverage of arable land in floodplains of the nine selected countries can be found in Italy, with 56 % (or almost 14 000 km²). The vast majority of these areas are located in northern Italy within the Po and Reno catchments (Map 2.1).

Pastures cover > 15 % of total floodplain areas for all nine countries combined. In Poland, pastures cover around one-third of floodplains, making it the most common land use category in the floodplains for this country and with pastures equally distributed over the Oder and Vistula catchments. Alluvial soils are nutrient-rich, which explains why arable land use, pastures and heterogeneous agricultural areas cover about two-thirds of the floodplain areas.

Forests cover around 9 % of floodplain areas, with Croatia having the highest floodplain coverage (nearly 30 %). Italy and Hungary reach only around 4 % of forests, and all other countries in this exercise are close to the average with around 10 % forest coverage.

Inland wetlands in floodplains cover, in total, about 4 % of the floodplain area, with Romania (with around 15 %) reaching the highest cover for this land use category. Artificial areas, being mostly urban areas, cover around 6 % of the assessed floodplains, with large differences between countries, from 25 % in Austria and 14 % in the Czech Republic to roughly 4 % in Hungary and only 2 % in Croatia.

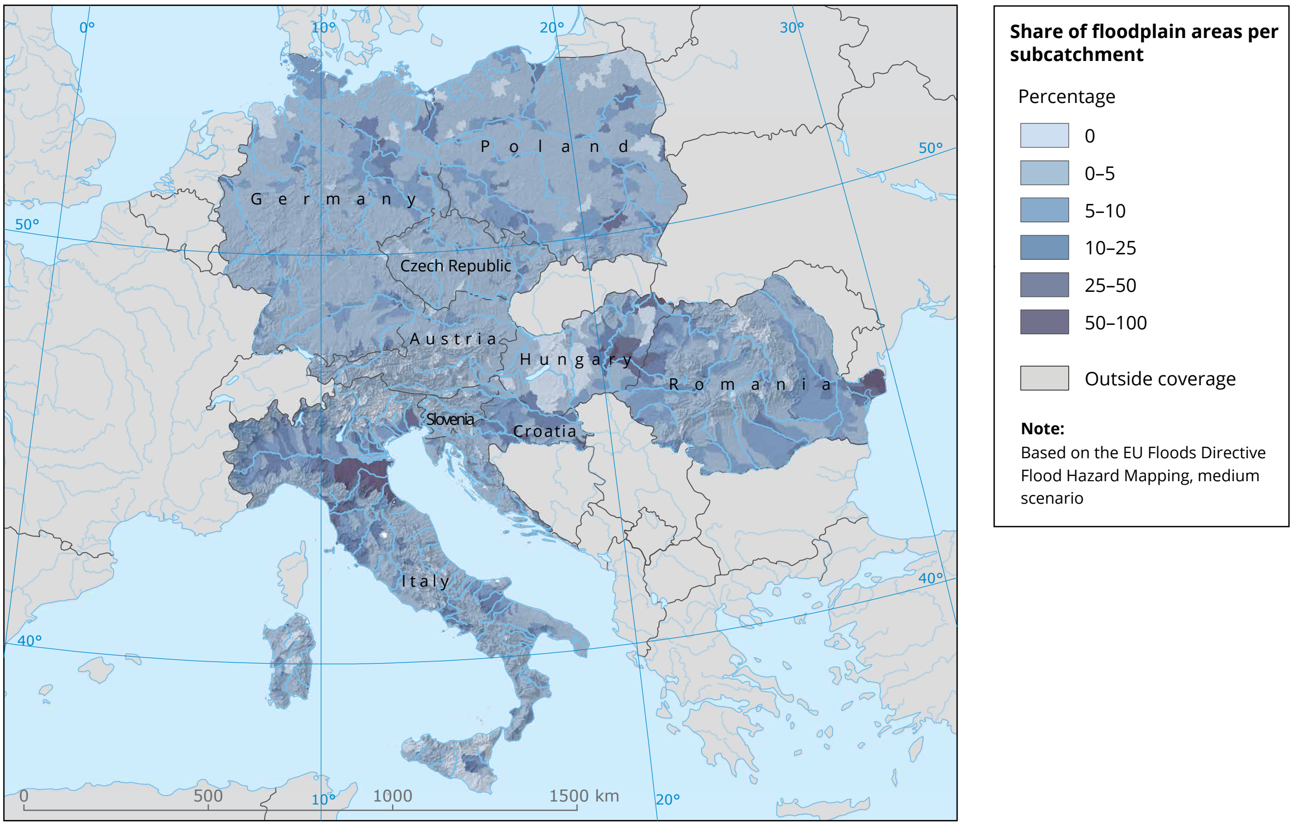
Note: ([a]) To be understood as an annual probability of occurrence of 1 %.

([b]) Although the flood hazard information could be viewed for all EU Member States as part of the flood hazard and risk maps, the map layers were reported to the EC or extractable from national web services only for the countries in Table 2.4 and Map 2.1. In addition, some countries reported data for some of their River Basin Districts (RBDs) but are excluded from the analysis as the information was missing for the majority of the RBDs.

2.3 Pressures on the functioning of floodplains

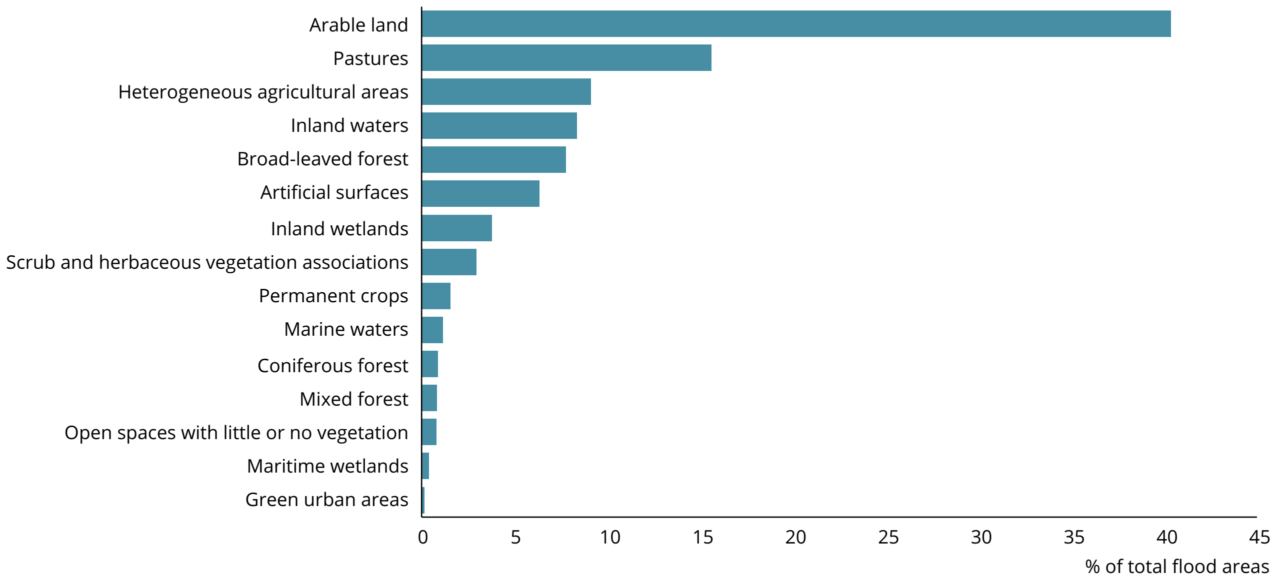
Pressures are the direct stresses of human activities on the environment (Stanners et al., 2007). A clear distinction between driving forces and pressures is not always possible, and depends on the environmental issue under consideration, but together they define the condition or state of an environment. In this section, we focus on the pressures that directly affect the functioning of the floodplain, including land use in the floodplain (see also Box 2.2), the hydrological regime and water-quality and the connectivity between river and floodplain. Socio-economic developments and climate change happen within the catchment as a whole and not just in the floodplains. These driving forces, with a wider spatial scope, are discussed separately in Chapter 3.

Map 2.1 Floodplain distribution



Note: Percentage of flood hazard area (medium probability) per subcatchment used as a proxy for floodplain coverage.

Figure 2.3 Share of land use types in floodplains



Note: Analysis undertaken for nine countries — Austria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland Romania and Slovenia (see Table 2.4) — with flooded areas under the medium scenario in the FHRMs as a proxy for floodplains and CLC version 2012.

Table 2.4 Areas of remaining floodplains approximated by the flooded area in 100-year probability flood hazard maps for selected countries

Country	Flood hazard area (km²)	Flood hazard area (%)
Austria	902	1.07
Croatia	3 917	6.92
Czech Republic	1 459	1.85
Germany ([a])	12 643	3.53
Hungary	6 216	6.68
Italy ([b])	24 681	8.21
Poland ([a])	10 979	3.52
Romania	14 111	5.92
Slovenia ([c])	352	1.74

Notes: ([a]) Some flood hazard areas especially closely to the coastline of North Sea (Germany) or Baltic Sea (Germany, Poland) are clearly prone to sea flooding.

([b]) At least in parts of Italy, an extensive network of irrigation and drainage channels have been considered when designating areas of potential significant flood risk.

([c]) Data obtained from national portal.

Source: Reporting obligation of Flood Hazard and Risk Maps for the Floods Directive (EU, 2007, Art. 6); http://rod.eionet.europa.eu/obligations/602, accessed 16 November 2015.

2.3.1 Hydromorphological changes

Hydromorphological changes involve changes in:

- the hydrological regime: quantity and dynamics of flow, connection to groundwater;
- changes in continuity and connectivity: the ability of sediment and migratory species to pass freely up and down rivers and laterally with the floodplain; and changes in morphology (i.e. physical habitat: compositions of substrate, width/depth variation, structure of bed, banks and riparian zone).

Hydrological regime

Although flood-control projects prevent and limit the impact of floods on populations and their assets, other benefits of water are also being employed, such as hydropower for electricity production, water supply and irrigation. For this purpose, more than 850 dams with reservoirs were built throughout Europe on larger ([10]) rivers, and more than half of these have an electricity production function (Map 2.2). The Alpine region has the highest density of dams, but more than 130 dams can be found on the Danube and its tributaries, and as many are found in Spain on larger rivers only. On the Rhone, there are more than 30 dams, and on the Rhine, there are seven. Dams pose barriers to the movement of aquatic species and, combined with hydropower production, they bring the risk of fish entrainment in turbine intakes. They alter the flow regime in the river and the structure of the reservoir shore zone habitat. Sediment transport in the river is affected by retention in the reservoirs, which may lead to erosion and an altered structure and condition for the bed and banks of downstream river stretches. The construction of the sequence of dams on the middle Ebro impacted its hydrological regime, sediment transport, morphology and ecology (Magdaleno Mas, 2011).

Dams with reservoirs are designed in a way that extreme floods would not result in a breach as a result of overtopping and sudden loss of stored water. No damage to the structures is allowed to occur during a flood that just uses the full amount of controlled reservoir storage space.

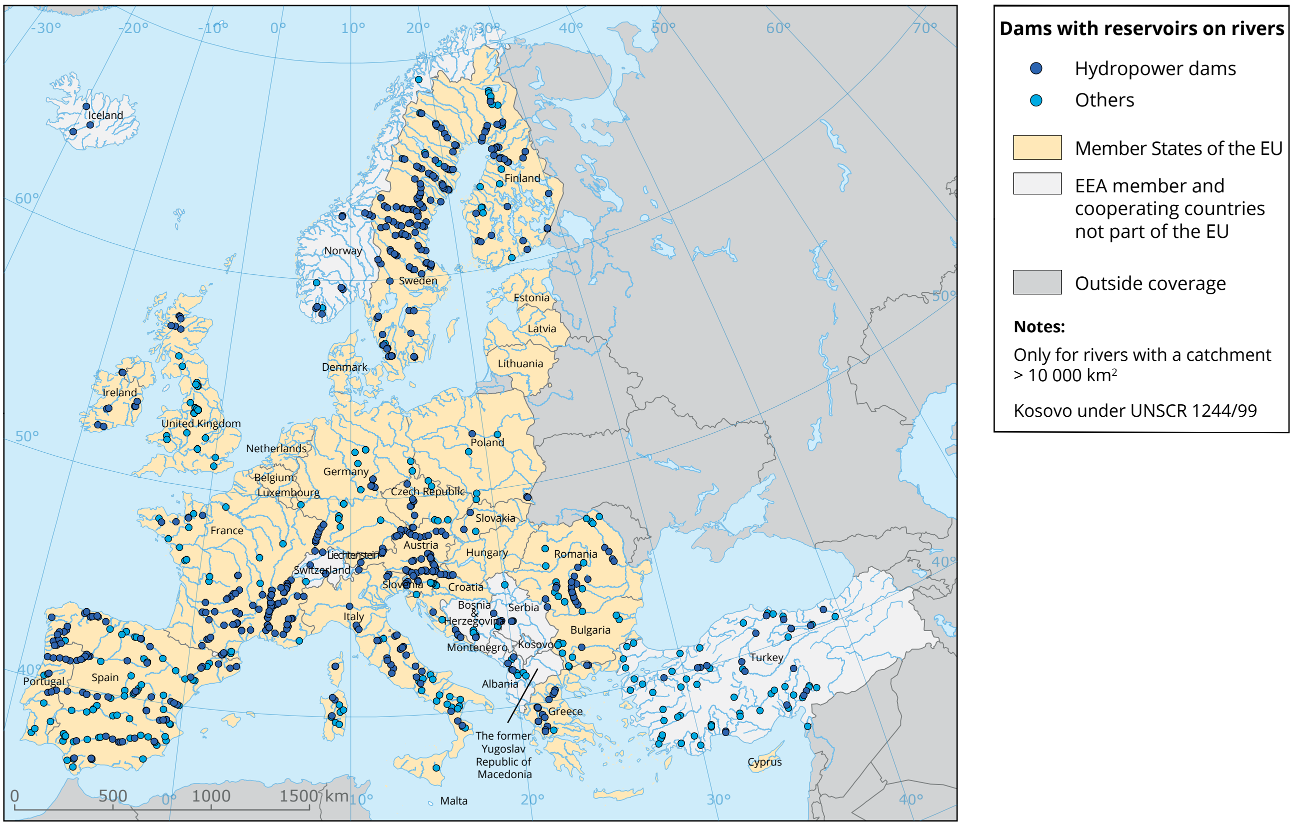
General recommendations for the hydrological design of dams that are built primarily for flood mitigation are based on two fundamental conditions: 1) hydrological dam safety; and 2) the level of protection against flooding of the direct hinterland and downstream areas. Flood-protection levels differ between rural and urban areas: in areas with major cities or high population density and if the economic, social and environmental considerations are favourable, return periods of 500, 1 000 or even 10 000 years — as is the case in many countries — may be justified.

Reservoirs of hydropower facilities on large rivers usually store water on a permanent basis within the safety margins of the construction. The optimal water-level management in the reservoirs for hydropower must not be the same as for flood reduction and therefore they do not always function as a significant flood-reduction measure. In addition, reservoirs can alter the timing of flooding. However, in a country like Finland, where water-retention in floodplains is limited, hydropower reservoirs have a significant role in flood-protection and this role is included in water regulation permits.

The hydrological regime is also expected to change as a result of climate change, despite the many unknown factors and uncertainties that still exist (see Section 3.2), which will lead to more extreme events (both floods and droughts) in some areas, an overall decrease of

([10]) Rivers with catchment areas > 10 000 km².

Map 2.2 Dams with reservoirs on rivers in Europe



discharge in others, or in changes in the occurrence of floods during the year. Land use change can affect the hydrological regime by reducing the retention capacity of a catchment, for example by soil sealing or compaction (leading to more extreme floods and low flows), by affecting the annual evapotranspiration (e.g. in case of deforestation) or by altering erosion intensity and thus the delivery of sediment to river channels.

Connectivity

Connectivity has a longitudinal dimension (the ability of sediment and nutrients to flow freely from upstream to downstream, the ability of organisms to move either way) and a transversal dimension (exchange of water, nutrients, sediments and organisms between the riverbed and the floodplain).

Various types of man-made infrastructures have a negative effect on connectivity: dams retain sediments and prohibit migration of water-borne organisms, ship locks pose barriers to these organisms, lateral flood-protection works (dykes) cut off floodplains from the river. In the remaining active floodplain area, inundations tend to become deeper than under natural conditions, because the area available for discharge and storage of water becomes smaller. By contrast, in the cut-off floodplain, inundation frequency is reduced strongly, to the recurrence interval for which the dykes were designed to fail or be overtopped. In many European countries, river dyke construction started in the Middle Ages, but because of technical progress the greatest impact of closing and reinforcing of dykes on floodplains in Europe was seen in the 19th and 20th centuries. Today, along many European rivers, only 10–30 % of the former floodplain is still functioning as inundation retention area for high and medium flooding events (see Section 2.2.2).

Morphology

In the 19th and 20th centuries, technical measures to improve navigability were implemented at a large scale in Europe. Measures included dredging, the construction of groynes to concentrate the flow and to maintain a minimum water depth, bank-protection to prevent erosion and subsequent silting, channelisation and straightening of river beds, construction of weirs and connected ship-locks to control the water level, and the construction of channels with controlled water levels parallel to the river. These measures have had a large impact on the river morphology, reducing such elements as sandbars and islands, reducing land–water transitional areas, flow velocity diversity, erosion and sedimentation processes and transversal and longitudinal connection. This, in turn, has led to a dramatic loss of river and floodplain biodiversity over the past century.

A prominent example in central Europe is the straightening of the Upper Rhine, the border river between Germany and France, by the engineer Johann Gottfried Tulla during the 19th century (Blackbourn, 2007), followed in 20th century by the construction of dams for hydropower and navigation between Basel and Iffezheim. Today, most parts of the alluvial zones have been disconnected from the discharge dynamics (Blackbourn, 2007; Schneider, 2010).

Dramatic floodplain modification has also been reported for the Rivers Tisza and Danube for land reclamation, hydropower and technical flood-retention measures. Compared with the 'ancient Danube', with an estimated cross-section close to Vienna of up to 100 km, the German and Austrian river stretch of the Danube is now mostly impounded for hydropower and navigation. These hydraulic impacts started in the 19th century, but continued until the end of the 20th century and resulted in disconnected riparian floodplains with a multitude of ecological consequences (Hohensinner et al., 2004; Schneider, 2010). In the late 1980s, the Gabčíkovo dam project along the Danube in Slovakia, close to the Hungarian border, was one of the last big projects to impact the Danube floodplain (Balon and Holčík, 1999). Some of the most intact floodplains remain in Croatia, Serbia or Bosnia and Herzegovina, but these are under pressure from navigation infrastructure or hydropower plans (Schwarz, 2010, 2013; Zarfl et al., 2015).

For the Austrian Danube floodplain, channelisation and the construction of hydropower plants resulted in a truncated fluvial system. Consequently, gravel/sand bars and vegetated islands decreased by 94 % and 97 %, respectively, whereas the area of the various backwaters doubled. In 1991, the former 'flow pulse' was halved as a result of artificial levees and embankments, greatly diminishing hydrological connectivity and decoupling large areas of the floodplain from the main river bed or channel. Active overflow, formerly playing an important part, is now replaced by backwater flooding and seepage inflow in isolated water bodies (Hohensinner et al., 2004).

The River Rhone in France has been modified by numerous uses and activities, such as navigation, irrigation, flood-protection or hydroelectricity, and over the past centuries has lost its floodplain connectivity. Embankments, dams and groin constructions, water diversion, and secondary channels with artificial cut-off generated severe morphological changes such as channel degradation and narrowing and bank stabilisation. These changes resulted in a fundamental modification of flowing conditions during floods and connections between river bed and floodplain ecosystems (Bravard, 2002; Dufour et al., 2008; Provansal et al., 2014; Raccasi, 2008).

2.3.2 Pollution and historical contamination of floodplains

In Europe, pollution in rivers (trace metals, nutrients, persistent organic pollutants, etc.) increased considerably during the 19th and 20th centuries, mainly as a result of mining and industrial activities. Other important sources were sewage discharge, run-off and atmospheric deposition. In the past decades, water-quality (in terms of chemical status) has improved significantly in many EU Member States owing to the treatment of urban waste water (EU, 1991) and the implementation of the WFD (EU, 2000). Although concentrations of harmful substances have decreased in many European rivers in recent decades, managing diffuse pollution remains a big challenge in many European river basins (EEA, 2012a). As river floodplains perform water-quality functions during floods, those areas still show high concentrations of pollutants compared with natural values and future target quality levels. During (extreme) flood events severe problems can arise in river catchments; not only the amounts of transported urban wastewaters may increase but, also, formerly deposited contaminants from floodplain soils might be remobilised. Therefore, floodplains may be both sinks for several pollutants and sources of a legacy of past pollution and, simultaneously, still fulfil the water purification function (Schulz-Zunkel and Krueger, 2009).

Redox processes in combination with pH-value ([11]) changes are the most important factors that determine the remobilisation of pollutants triggered by hydrological conditions within floodplains and across river floodplain gradients (Blackwell and Maltby, 2006; Frohne et al., 2015; Schulz-Zunkel et al., 2013). However, bioavailability of pollutants is not a constant factor and the quantification of pollutant fate, particularly based on changing biogeochemical conditions (e.g. during fluctuations between floods and droughts), is still lacking. Moreover, mobile levels of

([11]) pH: a numeric scale used to specify the acidity or alkalinity of an aqueous solution.

pollutants in the soil solution do not indicate whether they are remobilised from the legacy of past pollution or whether they are newly imported into the system. In addition, it remains unclear whether or not these substances will be transported to water bodies or plants and therefore potentially have toxicological effects. Consequently, greater understanding of pollutant dynamics, including the role and behaviour of transported sediments and floodplain soils on water-quality aspects as regards the aims of the WFD, are crucial.

2.4 Floodplain management and restoration

The complexity of floodplain management, with highly dynamic ecosystems and long-term socio-economic pressures, requires holistic approaches in which scientific evidence and expert knowledge are operationalised for policy needs (Antrop et al., 2013). Floodplains originally provided a high variety and quantity of ecosystem services (and biodiversity hot spots) but in many cases experienced strong human impacts that affected the delivery of ecosystem services. The impact of interventions upstream on the more downstream-located regions and finally on the total ecosystem services provided requires in-depth knowledge and understanding of the complex floodplain ecosystems (Scholz et al., 2012). It is supposed that floodplains are particularly vulnerable to the impacts of climate change and, therefore, well-planned floodplain management is increasingly important while demand for floodplain ecosystem services are growing (Capon et al., 2013).

When remaining active floodplains are compared with floodplains that have been cut off from the inundation regime, the remaining floodplains show a much greater ability to act as flood-retention areas, as reservoirs for groundwater, as filters (or sinks) for sediments and dissolved pollutants, as carbon sinks, recreation areas and natural habitats for highly specialised flora and fauna (e.g. Scholz et al., 2012). They are also natural flood-protection areas that delay the discharge of flood waves and, thus, contribute to the mitigation of flood peaks, especially when the floodplains are covered with near-natural forests (Hughes, 2003; Moss and Monstadt, 2008).

To maintain or restore the natural values of floodplains, more is needed than keeping the water level and discharge of its adjacent river between a certain minimum and maximum level. Ecological flows include the variation of water levels over time. A changed timing of high and low water flows is important next to changed quantities of water available, as time changes can be extremely problematic for many species. Developed within the context of the WFD, but easily expanded towards the functioning of natural floodplains, ecological flows are defined as 'an hydrological regime consistent with the achievement of the environmental objectives [...] in natural surface water bodies' (EC, 2015d).

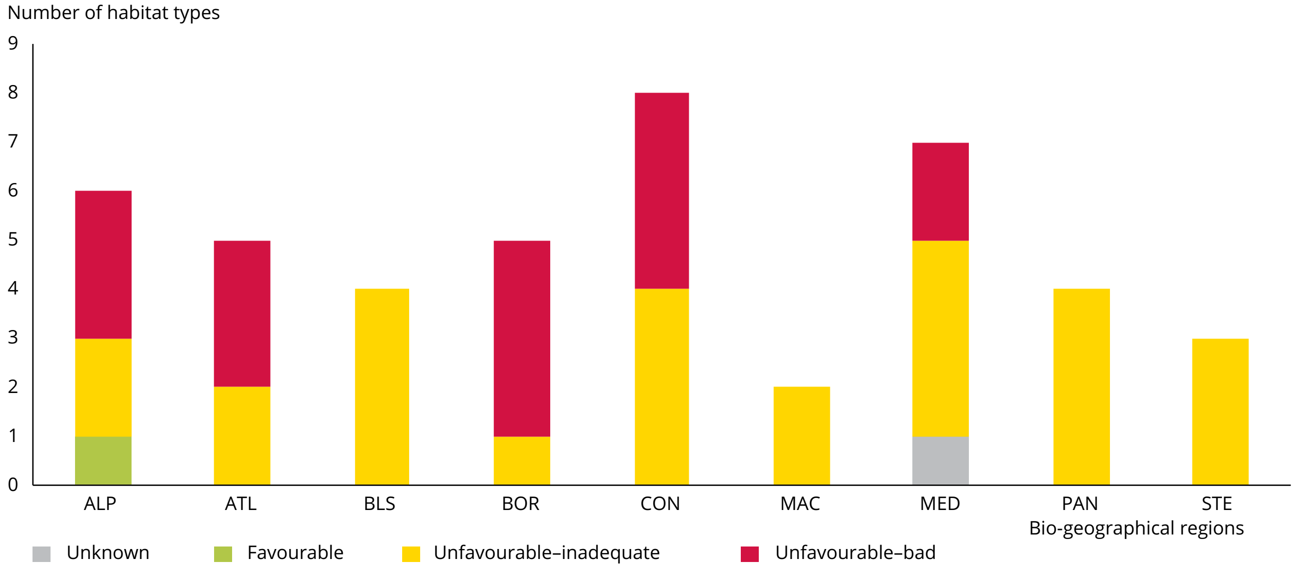
2.4.1 Protection of the natural values of floodplains

Remaining floodplains are important to fulfil the goals of different European directives such as the WFD, the Floods Directive or the Birds and Habitats Directives (see Chapter 4). The riparian zones are important biological quality components to assess the ecological structure and status. According to the Floods Directive, most European countries have designated flood-retention areas, which are very often legally protected, to manage flood events and to avoid unsuitable land uses. Because of the high biodiversity values, many of these flood-retention areas at the same time overlap with protected sites for nature conservation, such as the Natura 2000 network.

Floodplains contain a high diversity of habitats and species (see Sections 1.3 and 2.1) and most of the natural or semi-natural floodplain habitats are listed in Annex 1 of the Habitats Directive (EU, 1992) and are protected at national level. Floodplain habitats are not only covered in the category of freshwater habitats, but can also be found in the categories of bogs and mires, grasslands and forest. Nevertheless, in most biogeographic regions the conversation status (EU, 1992, Art. 17) still remains in unfavourable condition, being classified as 'unfavourable-bad' or at least 'unfavourable-inadequate' (EEA, 2015f). Results for different forest types occurring in floodplains, including Mediterranean riparian forest and wetland forest, on organic soils are shown as an example for the assessments (Figure 2.4), given the importance of forests in water-quantity regulation (see Box 2.3).

Besides restoration of the former floodplains and habitats (see Section 2.4.2), protection of the valuable areas that are left must be assured and remain a priority, as no restoration can reach the level of ecosystem services provided by the intact reference landscape (Rey Benayas et al., 2009; Schindler et al., 2014). The interventions in floodplains and the effects on biodiversity lead to the conclusion that there is often a mismatch in spatial and temporal scales between scattered scientific evidence and the holistic approach needed by decision-makers (Schindler et al., 2013). These spatial aspects go beyond the areal requirements (minimum area) needed to deliver a certain level of ecosystem services, but also include spatial

Figure 2.4 Conservation status of floodplain forest habitats



Notes: ALP, Alpine; ATL, Atlantic; BLS, Black Seas; BOR, Boreal; CON, Continental; MAC, Macaronesian; MED, Mediterranean; PAN, Pannonian, STE, Steppic.

For EU-27 level and per biogeographic region. Results of nine forest types occurring in floodplains from Annex 1 of the Habitats Directive have been aggregated:
9080*: Fennoscandian deciduous swamp woods
9160: Sub-Atlantic and medio-European oak/oak-hornbeam forests
91D0*: Bog woodland
91E0*: Alluvial forests with Alnus glutinosa and Fraxinus excelsior
91F0: Riparian mixed forest of Quercus robur and Ulmus laevis,
92A0: Salix alba and Populus alba galleries
92B0: Riparian formations on intermittent Mediterranean courses Rhodo
92C0: Platanus orientalis and Liquidambar orientalis woods
92D0: Southern riparian galleries and Nerio-Tamaric thickets
Data aggregated from Eionet — ETC/BD 2015: Online report on Article 17 of the Habitats Directive (2007–2012) http://bd.eionet.europa.eu/article17/reports2012/, accessed 16 November 2015.

Source: http://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-1, accessed 16 November 2015.

Box 2.3 Forests can help prevent floods (and droughts)

One-third of European territory is covered by (mostly managed) forests and these can retain excess rainwater, prevent extreme run-offs and reduce the damage from flooding. They can also help mitigate the effects of droughts. Forests are essential for human well-being and provide a wide range of ecosystem services to society, including 'water-retention', which is defined as the water absorbed or used by forests. A better understanding of the role of water-retention can help in the development of measures to tackle the effects of climate change and extreme weather events (EEA, 2015h).

The volume of water retained by forests depends on characteristics such as forest cover area, the length of vegetation growing season, tree composition and tree density, as well as the age and the number of layers of vegetation cover. Water-retention by forests affects the amount and timing of the water delivered to streams and groundwater by increasing and maintaining infiltration and storage capacity of the soil. Forests can soak up excess rainwater, preventing run-offs and damage from flooding. By releasing water in the dry season, forests help to provide clean water and to mitigate the effects of droughts.

The water-retention potential tends to increase along with the extent of forest cover in a water basin. Compared with basins with a forest cover of 10 %, total water-retention is 25 % and 50 % higher in water basins where the forest cover is more than 30 % and 70 %, respectively. Coniferous forests in general retain 10 % more water than broadleaved forests or mixed forests.

Despite its important role, water-retention by forests cannot be promoted as a one-size-fits-all solution. Instead, water-retention should be considered on a case-by-case basis in accordance with local and regional ecological and hydrological conditions, as proposed in the natural water-retention measures catalogue of the EC (see Box 2.4).

Source: EEA, 2015h.

composition (patterns of different ecosystems) and spatial configuration such as buffer strips, connections and corridors (Bastian et al., 2012). The same goes for the time dimension, where there are minimum time requirements for the generation of a particular ecosystem service as well as complex sequences in the use of an ecosystem service to enhance the benefits and time lags between the supply and demand or use of an ecosystem service (Bastian et al., 2012).

Where the water-storage role of floodplains and wetlands gets increased attention as an ecosystem service, ecology-based measures rarely receive uniquely positive feedback from different stakeholders (Grygoruk et al., 2013). Flooding, which normally occurs naturally and regularly in lowland floodplains, becomes a limiting factor for agricultural activities and an obstacle for economic development. Drainage as a pressure is increasing with broad-scale degradation of the fresh water-dependent ecosystems. The true economic dimension of water storage in floodplains is, however, more profitable for a broad range of stakeholders and potentially affected people than it appears negative for agriculture (Grygoruk et al., 2013).

In economic terms, the benefit of water storage in the floodplain is often compared with the benefit of storage in artificial reservoirs, although the total picture needs to include other ecosystem services as well, all of which have their own economic value as well as the value of the synergies between ecosystem services. In doing so, the monetary or economic value of water storage on a unit of land cannot be substituted by flood-related losses, but becomes one element in balanced calculations of whether to drain or keep the floodplain (Grygoruk et al., 2013). Such an ecological–economic assessment — now extensively studied (e.g. Bateman et al., 2013; Burkhard et al., 2013; Maes et al., 2012; Sullivan, 2012) — is a basic requirement for sustainable development and a necessity for environmental management at country level (Lawton and Rudd, 2013).

A sustainable management of floodplains could at least minimise the eco-toxicological effects of pollutants and their uptake through plants by restricting agricultural use. It promotes the widening of the active floodplain areas in terms of connecting rivers to their adjacent floodplains. This is highly important as floodplains fulfil several ecosystem functions and services. Water purification is one of them; floodplains may retain several pollutants and nutrients from river water during inundation events or phases of high groundwater levels (Hoffmann et al., 2009; Natho et al., 2013). Consequently, an increase of pollutant and nutrient-retention in floodplains supports the efforts undertaken to fulfil the aims of the WFD.

The sum of all inundated floodplains in Germany can retain up to 42 000 tonnes of nitrogen and 1 200 tonnes of phosphorus per year. This equals a yearly purification service saving of EUR 500 million in avoided costs for water treatment in sewage plants (Natho, 2014; Scholz et al., 2012).

2.4.2 Floodplain restoration in Europe

Floodplain restoration refers to the creation of ecosystems that are typical for floodplains, which exhibit a hydrological link between the river and the adjacent land. The term restoration as we use it in this report refers only to rehabilitation or enhancement of the ecological functions of rivers and their floodplains (Moss and Monstadt, 2008). Restoration and rehabilitation of floodplains has showed that enhanced ecosystem services provide a consistently increased multifunctionality of the area (Schindler et al., 2014). Floodplain restoration is an important measure to give more rooms for rivers, and in particular to reduce flood hazards and prevent such events from becoming disasters.

Natural floodplain management requires a specific set of measures to reduce flood risk and improve natural floodplain functioning at the same time. These measures can be aimed at both reducing the flooding probability and minimising the potential damage. Natural flood risk-reduction measures contribute to the restoration of the characteristic hydrological and geomorphological dynamics of rivers and floodplains and ecological restoration for biodiversity. In areas that are highly developed or that have been developed for long periods of time in particular, it is (almost) impossible to go back to a complete natural state. However, Natural Water Retention Measures (NWRMs) (see Box 2.4) like artificial wetlands, even on a small scale, help to keep farmland soil out of rivers and reduce river pollution by nutrients (Ockenden et al., 2014).

Target 2 of the Biodiversity Strategy for 2020 (EC, 2011a) describes that 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems'. As an outcome of one of the related actions, a strategic framework was developed to set priorities for ecosystem restoration at subnational, national and EU level (Lammerant et al., 2014). Restoration activities have taken place in Member States (see Boxes 2.5 and 2.6) but have not yet halted the trend of degradation of ecosystems and services. Outside the Natura 200 network, in particular, much remains to be done to halt the loss of ordinary biodiversity (EEA, 2015c).

Box 2.4 Natural Water Retention Measures

Natural Water Retention Measures (NWRMs) are a nature-based approach to pursue the objectives of water management, providing a variety of co-benefits in terms of biodiversity enhancement, greenhouse gas mitigation, energy saving or rural development opportunities (EC, 2015f). These co-benefits create opportunities to involve different stakeholders and require cooperation between policy areas including agriculture, forestry, energy and tourism but also include the possibility that no one might be interested in taking the initiative, as the benefits are varied and sparsely distributed.

Natural water-retention is explicitly mentioned in the EU Floods Directive (EU, 2007) and the maximisation of its use forms part of specific objectives of the Water Blueprint (EC, 2012d). Other restoration measures for natural areas, like remeandering of natural ponds are (indirectly) recommended by a note on better environmental options for flood risk management (EC, 2011d) and are seen as a better environmental option and alternative to hard (grey) infrastructure. 'Flood risk management should work with nature, rather than against it' (EC, 2011d). Where the WFD (EU, 2000) has the water body as a central concept, limited attention is given to riparian zones which might hinder the implementation of NWRMs to its full potential (EC, 2015g). NWRMs call for an integration, not only between the WFD and the Floods Directive but also between nature legislation and all policy fields, where water and land planning needs careful coordination (EC, 2015g).

Most of the NWRMs have a long-term time horizon, where the effectiveness and benefits of a measure become visible only after some time; they need a large spatial scale of implementation, like a catchment, to be effective, so one needs to find space on land that is often already serving another purpose (EC, 2015g). This can be a challenge or even barrier to implementation, as society can feel less concerned about long-term impacts and benefits that are more uncertain than short-term costs (EC, 2012c). In addition, the fact that several NWRMs require a commitment for regular management and maintenance can be an additional challenge.

Financing NWRMs can be challenging, as there are many beneficiaries and the financing sources used for traditional flood risk management based on infrastructure works are not always available. Even when NWRMs are more cost-efficient than 'grey' infrastructure providing the same flood-protection, funding for implementation and maintenance still has to be found (EC, 2015i). In Section 4.2, some of the financing sources available for NWRMs are discussed in more detail.

However, there is evidence to suggest that NWRMs can be effective and cost-beneficial, especially over a longer time horizon and in win–win situations where costs and benefits are distributed among several stakeholders (EC, 2015g). Spatial planning activities could provide the appropriate room to bring the different needs and constraints of stakeholders together (Parrod, 2014).

Choosing the right NWRM in connection with one objective is already far from straightforward, and adding multiple objectives makes it even more complicated (EC, 2015h) and can require years or even decades for preparation and public involvement. The mix of NWRMs with other structural and non-structural measures will always need to be site-specific and robust to changing conditions, including climate change (Santato et al., 2013). Many NWRMs are low-regret measures regarding climate change adaptation (Borchers, 2014), yielding benefits even in the absence of climate change, and are sufficiently flexible to be adapted to new insights at a later stage. A single NWRM is unlikely to significantly change the flood risk in a catchment of the status of a water body. Nevertheless, the widespread use of NWRMs can make significant contributions to meeting flood risk objectives, water-quality objectives and nature objectives, while improving financing possibilities, finding the best adapted solution for the local situation, increasing public acceptance and overcoming concentration on individual policies (EC, 2015h).

Source: For more information see http://www.nwrm.eu, accessed 16 November 2015.

Whereas structural measures mainly deal with flood control, natural flood risk-reduction measures comprise flood control, use and retreat, regulation, financial stimulation and compensation measures (Pichler et al., 2009). However, the whole discussion has to focus on ecosystem services that are provided and the co-benefits provided by natural flood risk-reduction measures (EEA and ETC/ICM, 2015) rather than on the somewhat arbitrary distinction between structural and non-structural measures or grey and green measures. A ring dyke around a floodplain is longer than a straight dyke along the river. Nevertheless, the former leaves more room for water-retention, self-purification, sediment accumulation, recreation, and many other ecosystem services. Case studies in the United Kingdom (Pettifer and Kay, 2012) support the 'intermediate disturbance hypothesis', where sites that are frequently and never flooded are less diverse in terms of biodiversity than those that are sometimes disturbed. This calls for sustainable flood risk management approaches with measures that work with natural processes to allow intermediate levels of flooding.

Box 2.5 Restoration projects in Europe

During the 1990s, interest in river restoration increased across Europe. Initially, restoration was mainly focused on the river channel itself and on aquatic ecology, but since the FLOBAR2 project (Hughes, 2003) and the establishment of a European Centre for River Restoration (ECRR) in 1995, floodplain restoration got increased attention as an essential part of sustainable water management. A RiverWiki-database of the RESTORE project contains almost 1 000 river restoration case studies, but only a minority of the completed measures are directly related to floodplain restoration and are mainly floodplain reconnections, riparian tree planting, removal of exotic plants as well as wetland and backwater creation. Many restoration projects in rivers and floodplains across Europe were also initiated with the help the EU's financial instrument supporting environmental, nature conservation and climate action projects (LIFE).

Also in the NWRM initiative (see Box 2.4), a catalogue of around 125 case studies can be found, including measures focusing on floodplain restoration that can mainly be found under the hydromorphology measures: river wetland and floodplain restoration and management, restoration and reconnection of seasonal streams or oxbow lakes, elimination of riverbank protection, renaturalisation of polder areas, etc.

Sources: http://www.ecrr.org/, https://restorerivers.eu/wiki/, http://www.nwrm.eu/list-of-all-case-studies and LIFE database (the EU's financial instrument supporting environmental, nature conservation and climate action projects), http://ec.europa.eu/environment/life/project/Projects/index.cfm, all accessed 16 November 2015.

Box 2.6 River Mur recognised for effective river basin management

The River Mur flows through Austria, Slovenia, Hungary and Croatia before reaching the River Drava, a tributary of the Danube. The organisation managing the Mur Basin was awarded the second European River Prize during the 6th European River restoration conference (ERRC) in October 2014 (EEA, 2014f).

Systematic river regulation since the late 19th century has separated the river's loops, branches and floodplain forests, which are important for the health of natural systems. Modifications including hydropower stations (in the upper part) and embankments have also degraded habitats. Nonetheless, the Upper Mur is considered one of the most ecologically valuable rivers in Europe, not least because it is the natural breeding site of the Danube salmon. It also has the second largest alluvial forest in Austria, one of Europe's most species-rich habitats. The River Mur corridor in Slovenia is up to 1 km wide and has a high variety of typical plant and animal communities ranging from pioneer to mature stages, including Pannonian–Dinaric and Pontic–Caspian elements, with large floodplain forests and side arm systems (Globevnik and Mikoš, 2009).

Owing to its high biotic diversity, a large part of the Mur corridor in Slovenia has been designated a Natura 2000 site. The Natura-protected habitats are alluvial forests and hydrophilous tall herb fringe communities of floodplains. Nevertheless, ecological conditions for flood forest tree species in floodplains are deteriorating as a result of water shortages in oxbows, side arm channels and soils. The mouth of the River Mur is one of the last remaining preserved system lowland rivers in Europe. Here both rivers, the Drava and the Mur, are unregulated and continually create new habitats and restore existing ones, which maintains high biological diversity.

River management on the Mur has largely focused on restoring old structures and recovering natural river habitats by reconnecting them with the dynamic river-system. Besides environmental benefits, these measures have other advantages, including better passive flood-protection and new natural recreation areas for residents. Looking ahead, a section of the river will be designated in which hydropower plants will be prohibited. Such measures show that management of the Mur is a good example of policy integration and stakeholder dialogue, two elements that are vitally important in successful river basin management.

Changes in land use are often needed for the implementation of these measures. Therefore, spatial planning and stakeholder involvement are of vital importance when implementing a natural flood-defence scheme (Moss and Monstadt, 2008). The protection of existing naturally functioning river and floodplain systems also can be regarded as an important natural flood risk-reduction measure.

2.4.3 Efficiency and effectiveness of water-retention measures

NWRMs and other non-structural measures such as flood forecasting and early warning are integral parts of a modern integrated flood risk management (Pichler et al., 2009). NWRMs and the changes in land use that come with them are important to reach substantial flood risk reductions, but decision-makers keep coming back to water managers with questions about their efficiency and effectiveness. Effectiveness, a term also used in the WFD, is a result-based term and describes the degree of goal achievement in terms of risk reduction or moves towards risk reduction. Efficiency is a yield-based term and describes how an intended risk reduction or an effect towards risk reduction has been achieved economically. This is related to a cost–benefit analysis, and is a key concept in the programme of measures for the Floods Directive (EEA, 2012d; Pichler et al., 2009).

In general, the potential additional water-storage capacity of NWRMs like microponds or afforestation during floods is rather limited. As smaller and more frequent floods can still make a large contribution to the total risk, the risk-reduction capacity of NWRMs can be higher than expected from the hazard reduction (EEA, 2012d; Francés et al., 2008; Pichler et al., 2009).

When assessing the efficiency and effectiveness of NWRMs, two issues have to be kept in mind: complexity and competitiveness. Complexity refers to the fact that NWRMs are not implemented to reach one single goal (e.g. flood-protection), but come with a range of benefits. One should not forget that this can impose constraints on some sectors as well, because they perceive that their interests were better served by former practices than by NWRM (Ungvári, 2014). Competitiveness addresses the issue that NWRMs and nature-based solutions have to deliver comparable sector-level results on natural effectiveness, economic efficiency and ease of implementation.

3 Anthropogenic drivers

Driving forces and pressures form part of a framework to assess and manage environmental problems. The DPSIR framework describes interactions between the environment and society. Driving forces are the socio-economic (and cultural) forces driving human activities, which increase (or mitigate) pressures on the environment.

3.1 Socio-economic development and land use change

Demographic changes and economic developments have a direct impact on the intensity with which rivers are used for functions such as transport, hydropower production and cooling of power plants and industries. Moreover, part of such socio-economic developments are physically taking place in floodplains. As a result, the land use is changed (e.g. from a natural vegetation to an agricultural area, from an agricultural area to housing or industrial areas, or from natural vegetation to open water in the case of minerals mining). Part of the floodplains may also be used for infrastructure such as roads and power lines. Where land use is accompanied by significant investments, the changes may lead to the implementation of additional flood-protection measures.

Finally, land use changes outside the floodplains but within the catchment, such as shifts from forestry to agriculture, from pasture to arable land, from rain-fed to irrigated agriculture or from agricultural use to urbanised areas, can also function as drivers for changes in floodplains.

Intensification of economic uses in the floodplain and in the wider catchment brings about hydromorphological pressures, as discussed in Section 2.3.1.

Photo: © André Künzelmann/UFZ

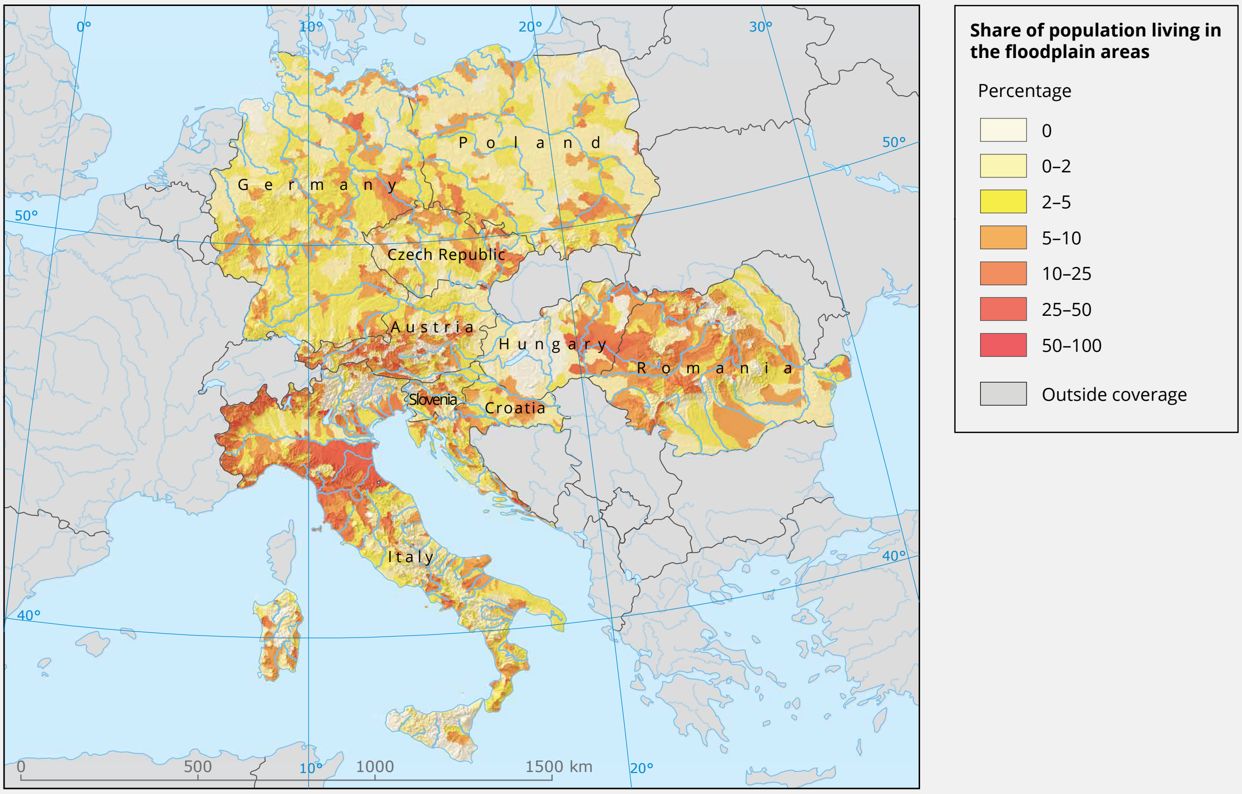
Data to illustrate the above socio-economic developments are only available as approximations (see Box 3.1 for population), first because the delineations of the administrative boundaries within Europe ([12]) do not coincide with floodplains or even river catchments and, second, because at EU level no maps with reliable delineations of floodplains (see Section 2.2) are available.

([12]) Nomenclature of territorial units for statistics (NUTS); see http://ec.europa.eu/eurostat/web/nuts/overview, accessed 16 November 2015.

Box 3.1 Populations in flood-prone areas

Based on the intersection of FHRMs reported for nine countries (see Box 2.2) and population density, more than 14 million people are living in areas flooded in a medium scenario with a 100-year return period. This represents 6 % of the entire population living in these countries (Map 3.1). The largest population living in flood-prone areas, namely 6.7 million people (11 % of total population), can be found in Italy and the majority of them in north Italy. However, the highest relative population living in flood hazard areas can be found in Hungary (18 % of the Hungarian population, that is, 1.8 million people). The most populated flood-prone settlements are located in the eastern part of the Great Hungarian floodplain of the Tisza and Körös catchments (e.g. Szeged and Szolnok). In Austria, Croatia, the Czech Republic and Romania, approximately 5 % of the population lives in flood hazard areas in the medium scenario, which is slightly more than in Slovenia (4 %) and in Poland and Germany (3 %). The most populated German flood-prone settlements are situated in the upper Elbe valley (e.g. Dresden). Moreover, there are higher population densities in flood hazard areas of the Middle Rhine and the Mosel, because of the narrow river valley.

Map 3.1 Share of the population living in flood-prone areas per subcatchment



3.2 Climate change

Climate change is expected to affect all water-related functions and policies discussed in Chapter 4 of this report (Ciscar et al., 2014; EC, 2013c; IPCC, 2014b). The shifts in the extremes, rather than the trend in the averages, are likely to be the biggest challenge for adaptation (IPCC, 2012) and are also likely to be the cost drivers for the adaptation of infrastructure (OECD, 2013).

Sea-level rises and increases in extreme rainfall are projected to further increase coastal, fluvial and pluvial flood risk in Europe and, without adaptive measures, will substantially increase flood damages (in terms of numbers of people affected, economic losses and, although less often quantified, most probably also cultural heritage and ecosystem services). Direct economic river flood damages in Europe have increased over recent decades but this is, to a large extent, influenced by increased exposure of people and economic assets and increased economic wealth. The number of events is, presumably, influenced by improved reporting particularly on the number of small loss events (EEA, 2015a).

To determine the effects of ongoing climate change in the pattern of loss data for floods remains elusive. Some areas in Europe show changes in river flood occurrence related to observed changes in extreme river discharge. Increasing extremes will presumably lead to greater losses. However, the future cost of floods in Europe will depend on several other key factors, including disaster risk management actions and changes in resilience and vulnerability, which are variable across hazards and regions (EEA, 2015a).

3.2.1 Variability of climate change and climate change impacts across Europe

Observed climate trends and future climate projections show regionally varying changes in temperature and rainfall in Europe, with projected increases in temperature throughout Europe, as well as increasing precipitation in northern Europe and decreasing precipitation in southern Europe. Climate projections show a marked increase in high temperature extremes, meteorological droughts and heavy precipitation events with variations across Europe, and small or no changes in wind speed extremes except for increases in winter wind speed extremes over central and northern Europe (IPCC, 2013). A changing seasonality, with warmer Scandinavian winters, will bring more precipitation as rain and less snowfall, causing fewer spring floods as a result of snowmelt.

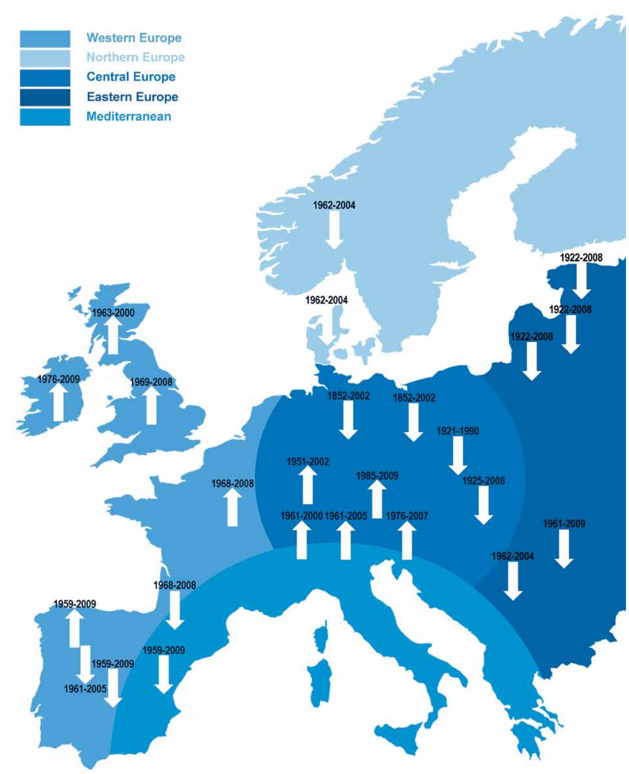
3.2.2 Fluvial flood regime changes

The available literature and dedicated studies performed to identify trends in mean annual discharges or annual maxima have recently been inventoried and summarised (Hall et al., 2014; IPCC, 2014b; EEA, 2016). The studies that were included in the inventory by Hall and colleagues converge in some broad-scale overall patterns, which can be summarised as follows (see also Figure 3.1):

- in western Europe:
  - a decrease in maximum annual flows in central Spain and the Douro Basin;
  - no consistent change in most regions in France, with the exceptions of increasing flood peaks in the north-east, decreasing high flows in the Pyrenees, and earlier snowmelt-related floods in the Alps;
  - increasing trends in annual high flows in Ireland and the United Kingdom;
- in Scandinavia, mixed patterns from which no conclusive overall pattern could be identified;
- in central Europe, an overall tendency towards increasing large floods, and in central, west and south Germany, Switzerland and Hungary increasing trends for large floods. Austria shows mixed results across the country, whereas in other parts of central Europe no conclusive trends could be identified;
- in eastern Europe, a majority of identified trends for decreasing annual maxima;
- decreasing trends in the Mediterranean.

These trends are, in most cases, not very firm and the uncertainties are high as a result of different monitoring approaches used, differences in underlying hydrological processes and different observation

Figure 3.1 Schematic summarising the observed flood changes in Europe



Note: The schematic summarises the outcomes of many different studies, which used different and not directly comparable change analysis methods and time periods. The arrows in the schematic indicate the majority of trends, including regions with weak and/or mixed change patterns. Areas with no or inconclusive studies owing to insufficient data (e.g. Italy) and inconclusive change signal (e.g. Sweden) are not shown.

Source: Hall et al., 2014.

periods. As (Hall et al., 2014) emphasise: 'don't regard the schematic as a stand-alone outcome, interpret it in combination with the original literature'.

In those cases in which a trend is identified, the next step is to the identify potential causes for that trends. Climate change is one, changes in land use, implementation of flood-protection measures, and changes in assessment methods are others.

Climate change is projected to affect the hydrology of river basins (IPCC, 2012, Chapter 3; IPCC, 2014a, Chapter 4). The occurrence of current 100-year return period discharges is projected to increase in continental Europe but decrease in some parts of northern and southern Europe by 2100 (Dankers and Feyen, 2008; Rojas et al., 2012). Although snowmelt floods may decrease, increased autumn and winter rainfall could lead to higher peak discharges in northern Europe (Lawrence and Hisdal, 2011).

3.2.3 Pluvial floods

Few studies have estimated future damages from inundation in response to an increase in intense rainfall (e.g. Willems et al., 2012). Pluvial flash floods are the result of short-duration extreme rainfall intensities, leading to excessive surface run-off and ponding. Processes that influence flash flood risk include increasing exposure from urban expansion, and forest fires that lead to erosion and increased surface run-off (Lasda et al., 2010).

Pluvial floods are of particular interest in urban areas, where the rainfall exceeds the capacity of urban drainage systems. Climate change impacts on extreme short-duration rainfall events in combination with urbanisation trends and related increases in impermeable surface areas may have significant impacts in terms of surcharge of urban drainage systems and pluvial flooding. Results so far indicate more problems with sewer surcharging, sewer flooding and more frequent sewer overflows (Willems et al., 2012). There are also many other types of severe consequences at the scales relevant to urban hydrology, such as sedimentation, water-quality or damage to infrastructure. In addition to regional differences in extreme rainfall and other meteorological changes, the precise impacts will also depend on local topography and on urban planning practices.

Extreme pluvial flooding should also be better integrated in the fluvial flood risk management. In densely populated areas, strong interactions exist between urban drainage and receiving surface waters. This can result in increased flood hazards owing to urban peak inflows in rivers and, for combined sewer systems, in peak pollution loads owing to sewer overflows.

The large degree of uncertainty that currently exists in climate change projections should not be an argument for delaying adaptation actions. An adaptive approach has to be established that both provides inherent flexibility and reversibility and avoids closing off options (Stern, 2007). Owing to similarities with the high uncertainties in future climate projections, the application of environmentally focused approaches to urban water and flood management would provide more timely achievement of objectives and enable more cost effective and feasible solutions. This adaptive approach involves active learning, hence recognising that flexibility is required as understanding increases (Pahl-Wostl, 2008).

The required investments to adapt storm water sewer systems to higher design precipitation events are huge. Mayors Adapt ([13]) is a covenant that was set up by the EC to engage cities in taking action to adapt to climate change (EC, 2014b). Cities that adopt the initiative commit to the development of a local adaptation strategy or the integration of adaptation to climate change into relevant existing plans. Mayors Adapt supports these activities, among others, by providing technical support, by providing a platform for greater engagement and networking by cities, and by raising public awareness about adaptation and the measures needed for it.

3.2.4 Groundwater flooding

Although groundwater flood risk is, in general, less of a concern across Europe than fluvial, pluvial and coastal flood risk, it presents a significant local or regional hazard in some areas. The climate change impacts with regard to groundwater are not certain, and over the long term will be influenced by relative changes in groundwater recharge associated with, for example in some regions of Europe, drier summers and wetter winters. Two of the principal challenges with regard to managing groundwater flood risk sustainably are:

- the long duration of events often associated with it; and
- the difficulty of 'managing' the flood water either while it remains in the ground or once it emerges.

([13]) See http://mayors-adapt.eu/, accessed 16 November 2015.

Photo: © André Künzelmann/UFZ

For those areas in Europe in which regional groundwater flooding is a current problem or where it may increase because of climate change, the relative changes in seasonal recharge need to be considered when developing a suitable adaptive approach.

3.2.5 Impacts of climate change on ecosystems

There is clear evidence that ecosystems in Europe are already responding to climate change (IPCC, 2014b). The direct impacts of climate change on ecosystems, related to temperature increase and changing precipitation patterns, are expected to be harmful. They can cause, among other things, habitat loss, changes in species composition because of differential invasion and decline of species, and general damage to ecosystems and ecosystems services that are not capable of responding fast enough to the changing conditions (IPCC, 2014b; EC, 2013b).

For this report, the impact of climate change on flood regimes is of particular interest. The seasonality of river flows may change depending on changes in rainfall patterns over the year and the contribution of melting snow to the discharge. Peaks and low flows are, for some rivers, expected to become more extreme. Water-quality can be negatively affected by higher temperatures and the flood water carries increased loads of sediments owing to erosion (EEA, 2016). Such changes can subsequently cause indirect impacts by inducing shifts in human land and water use and the implementation of adaptation measures (e.g. improved protection against flooding; construction of reservoirs to bridge dry spells) which cause additional competition with environmental needs (EC, 2013b).

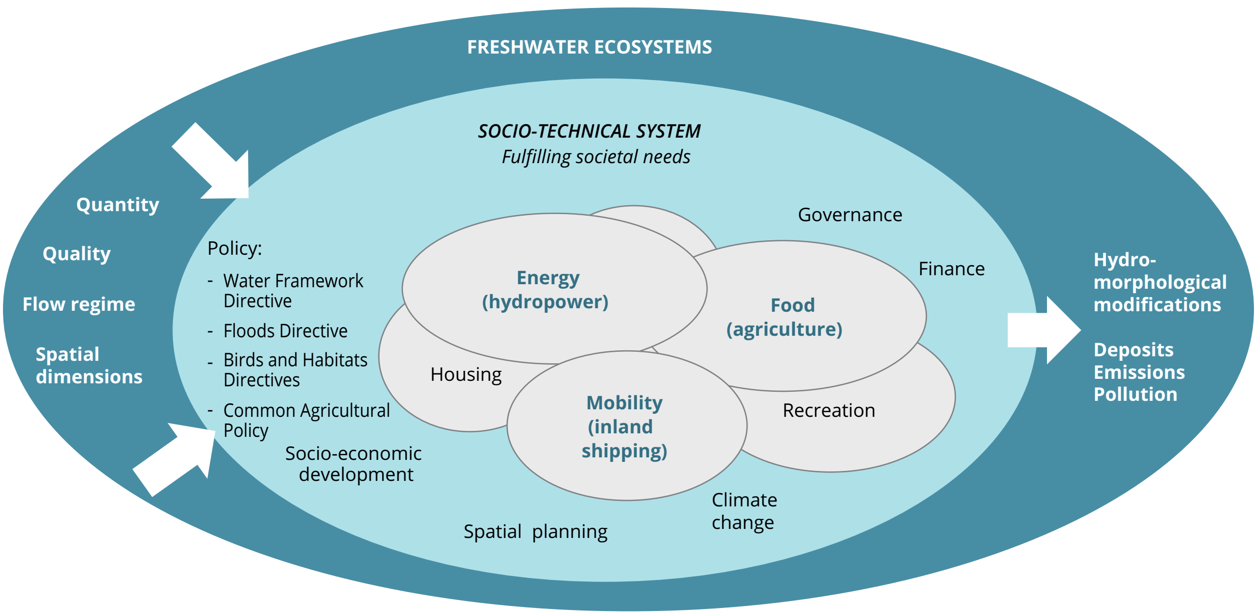
4 Policy developments and implementation

The management of flood plains and river catchments more generally has many objectives. Keeping flood hazards and risks at an acceptable level must be combined with other societal, economic and ecological needs. Agriculture, inland navigation, hydropower, forestry, recreation, protecting cultural heritage, housing and industry are among the most prominent socio-economic activities relevant in floodplain areas that are not too narrow or small. Mapping the demands of these sometimes conflicting interests, including their relative influence, and reconciling them with environmental protection and restoration to increase the ecosystem services delivered, is an increasingly relevant and complex task.

The aim of this chapter is to highlight recent developments and insights in EU policy and in research, as far as is relevant for the overlapping areas of flood risk management, flood vulnerability and environmental impacts of flooding. Our objective is not to provide full summaries of these policies and research projects, but to pick from all of these initiatives those elements that focus on the links between water, environment and economic policies and sectors.

Figure 4.1 gives a schematic overview of the contents of this chapter. The directly water-related directives and the water-related sectoral policies are discussed in Section 4.2, and the cross-cutting issues — including policies on driving forces such as climate change or spatial planning but also aspects of governance — which are of special interest for at least several policy fields, are described in Section 4.3. At the same time, one must be aware that there are other policies of importance for flood risk management and disaster risk reduction, for example the Risk Assessment and Mapping Guidelines for Disaster Management (EC, 2010), the Risk Management Capability Assessment Guidelines (EC, 2015a) or the Decision on a Union Civil Protection Mechanism (EU, 2013a). However, as they deal with neither environmental vulnerability directly nor natural floodplain management or restoration, they fall outside the scope of this report.

Figure 4.1 Schematic overview of the contents of Chapter 4



4.1 Disaster risk reduction

Disaster risk reduction (DRR) is the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters. Reducing exposure to hazards, lessening the vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction (see Figure 4.2).

In March 2015, the third United Nations World Conference on Disaster Risk Reduction was held in Sendai, Japan. The conference adopted the Sendai Framework for Disaster Risk Reduction 2015–2030 (UN, 2015). This framework aims for 'The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.' The Sendai Framework sets four specific priorities for action:

- understanding disaster risk;
- strengthening disaster risk governance;
- investing in disaster risk reduction for resilience and enhancing disaster preparedness;
- 'Build Back Better' in recovery, rehabilitation and reconstruction.

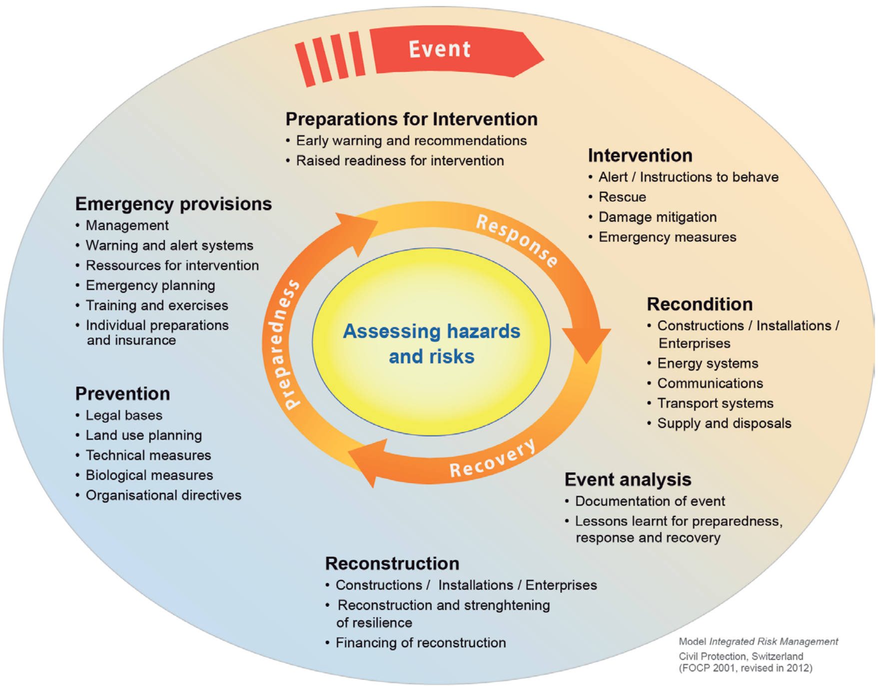
To support the assessment of global progress in achieving the outcome and goal of the Sendai Framework, seven global targets have been agreed, which aim to reduce the impacts of disasters, enhance preparedness, enhance international cooperation and develop and improve access to early warning systems.

The Sendai Framework attributes a primary role to reduce disaster risk to the state, although this responsibility should be shared with other stakeholders. It defines resilience as a priority and emphasises the importance of locally driven solutions. It pays attention to social vulnerability and recognises social processes and weak institutional arrangements as drivers of risk. It furthermore pays ample attention to environmental aspects. There is a strong recognition that reconstruction of ecosystems and nature-based solutions are crucial in the protection against disasters.

Disaster risk reduction and the Floods Directive

There are obvious differences in scope and legal status between the Sendai Framework and the Floods Directive, but they also have many similarities.

Figure 4.2 The Disaster Risk Reduction Cycle



Note: Example for Switzerland, variations in major steps, terminology and level of detail exist in different countries and organisations.

Source: Swiss Federal Office for Civil Protection (FOCP, 2014).

The Floods Directive deals with all aspects of the DRR Cycle, although it focuses on prevention, protection and preparation (the 'reducing vulnerability' part of the cycle, or the pre-event in Figure 4.2).

The French National Strategy for Flood Management gives a great deal of attention to prevention (avoid building), stating that it is the most effective measure to limit damage from flooding in areas that can be flooded. In all cases, making populations safe in areas protected by existing works calls for the sustained maintenance of the works in place. Although new urban developments in flood-prone areas, even when protected against some levels of risk, are not allowed, some general principles to improve the safety of assets located in the areas with flood risks are set up. These general principles are (General Directorate for Risk Prevention and Ministry of Ecology, Sustainable Development and Energy, 2014):

- strictly preserving floodplains in non-built-up areas, wet areas and dune areas along the coastline;
- banning building in areas that are extremely vulnerable to flooding;
- limiting the presence of sensitive equipment and reducing its vulnerability in flood risk areas to avoid excessively complicated crisis management,
- where building is possible, adapting it to the risk in question, for all new construction projects in areas vulnerable to flooding;
- ensuring that building is not allowed behind levees except where this is justified in urban areas or in areas of strategic importance;
- identifying areas that are dangerous to human life and studying how to make existing populations safe in these areas owing not only to monitoring, forecasting, warning and evacuation measures but also to relocation projects or by reinforcing protection or retention works.

Many of the new elements of the Sendai Framework are already included in the Floods Directive, namely stakeholder involvement, the importance of governance, ecosystems and eco-based solutions. Climate change is acknowledged in the Sendai Framework as a driver of disaster risk. In the Flood Risk Management Plans (FRMPs), climate change is receiving increasing attention. The Sendai Framework offers little guidance to governments to link DRR and adaptation planning and funding mechanisms. Actions highlighted include the use of climate change scenarios to inform risk assessments and maps, and collaboration across institutions for DRR and adaptation at all scales, as also promoted under the Floods Directive.

4.2 European policies influencing the management of floods and floodplains

Efficient and effective flood risk management planning cannot be based on the Floods Directive only. In terms of process, many links are made with the WFD, but more important are the content links for a sustainable flood risk management: first with the WFD and wider water legislation but also with the nature legislation. In addition, many thematic policies have an impact on and are impacted by flood risk management. These influences differ from place to place and can change over time. As agricultural policies are an important consideration for almost all of Europe, they are discussed separately.

4.2.1 Floods Directive

After indicating the units of management — which are, except for Italy and Ireland, the same as the river basin districts under the WFD — and the competent authorities responsible for the implementation of the Floods Directive, the first analysis was undertaken by EU Member States in the Preliminary Flood Risk Assessments (PFRAs), which were due in December 2011 (see Box 4.1).

A large majority (roughly two-thirds) of reported events were related to fluvial flooding, followed by surface water flooding from heavy rainfall and coastal water floods. Over 40 % of records were from floods for flood events from the year 2000 onwards (EC, 2015b). The PFRAs not only made information available about the physical flood characteristics of significant past floods, such as the source, mechanism and characteristics, but also about the consequences. When looking at the impacts, it becomes clear that economic damage is reported less frequently as 'not applicable' than the environmental impact. It is unclear if this is because environmental damage occurs less frequently or because of an inherent bias in the data, as economic impact were traditionally recorded in more detail (ETC/ICM, 2013).

Whereas the PFRAs made more information on the impacts of flooding available in a structured way (although often not quantified or in monetary terms), it is also obvious that PFRA reporting is in itself insufficient to function as the single database on floods and flood impacts in Europe (ETC/ICM, 2015b), as there are significant differences in the ways in which countries

Box 4.1 The EU Floods Directive

The purpose of the Floods Directive (EU, 2007) is to establish a framework for the assessment and management of flood risks, which aims to reduce the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods. The Floods Directive defines a series of process steps to be taken, including associated efforts on data collection and reporting, but it does not include specified targets (e.g. in terms of flood risk levels to be reached). The Floods Directive follows a 6-year cycle similar to that of the WFD (EU, 2000). The first cycle will be completed by the end of 2015 when EU Member States are scheduled to adopt and make available the first round of FRMPs.

reported past flood events. The next reporting cycle, in which a PFRA is due by the end of 2018, could benefit from additional guidance in order to obtain more homogeneous information across Member States (ETC/ICM, 2013). Examples of current heterogeneity include non-uniformity in the criteria by which flood events are declared 'significant', or the use of term 'not applicable' which sometimes means 'was checked and was not observed' and in other cases means 'we do not know because there are no data available'.

Although the structured way of reporting these impacts in categories is relatively basic, it contains information on human health (fatalities) and economic impacts as well as on impacts on the environment and cultural heritage that can be used in European overviews. Making this information available to the public is essential in raising awareness of flood risks ([14]).

After the selection of Areas of Potential Significant Flood Risk (EU, 2007, Art. 5), EU Member States had to develop on Flood Hazard and Risk Maps (FHRMs), which were due for the end of 2013. Although the in-depth review is ongoing in 2015, a partial overview (including the FHRMs of 32 units of management (UoMs)) shows that international coordination is lagging behind. From a subset of 18 UoMs, all of which are part of an international RBD, 11 presented flood hazard and flood risk maps for the area that is shared. In addition, only in five of them it is clear that coordination in the development of the maps has been achieved (WRc, 2015).

The Member States' reporting of the FHRMs suggests that almost 4 500 industrial installations are potentially affected by pluvial floods. In roughly half of the EU Member States, fluvial flooding with a probability of 1 % per year can be overlaid with protected areas (Kavvadas, 2015) as defined in the directives on drinking water (EU, 1998), birds (EU, 2010) and habitats (EU, 1992), urban wastewater treatment (EU, 1991) and the WFD (EU, 2000).

FRMPs are to be adopted and available by December 2015 and will be reported to the EC by March 2016. However, as FRMPs should be developed with the active involvement of interested parties (EU, 2007, Art. 10), draft FRMPs were still available when this report was produced in 2015.

While keeping in mind that only the draft FRMPs were available and that conclusions may change when the final versions become available, a screening of these plans reveals that > 90 % of those available included objectives for flood risk management and reduction of flood risks (WRc, 2015). However, these objectives are specific and measurable in only 25 % of the plans. Only in a very small minority of the plans were objectives for the use of preventive and protective measures listed, whereas, in contrast, almost 80 % of the plans included objectives on preparedness measures. Still lacking in many cases is the underpinning of how the individual measures contribute to the overall objectives set to reduce flood risk and towards more general water policy (environmental) objectives (WRc, 2015). Nevertheless, the proposed measures themselves are rather evenly distributed over the four types ([15]). As the Floods Directive has a framework approach, its success is dependent on the ambition of the Member States for its implementation and for measuring its progress (EC, 2015c). The development of a European database on flood impacts (see Chapter 1) and initiatives like disaster-loss data recording guidelines (De Groeve et al., 2013, 2014) are important for the measurement of success.

Coordination between Member States on objectives and measures has been achieved in half of the RBDs/UoMs that are part of international RBDs/UoMs, so — as for the FHRMs — there seems to be ample room for further improvements. The same is true for climate change and socio-economic changes (and resulting pressures such as changing land use) and in particular for the quantification of these future impacts, as they are key elements of flood risk management (EC, 2015c).

([14]) For links to the European database on past floods, see Chapter 1.
([15]) Measures are divided into four categories: Prevention, Protection, Preparation and Recovery/Review (EC, 2013a).

With the first cycle of implementation for the Floods Directive almost ending with the availability of the FRMPs, a preliminary evaluation of where the implementation of this directive leads us to can be made. In general, it is clear that the improved estimations (and, in a way, prioritisation within Member States) of areas with the potential to experience significant floods and the values at risk will become publicly available. Although difficult to quantify, it is expected that this will lead to an increased flood risk awareness among the general public.

Given the importance of synergies with the WFD and other policies (see Section 4.1.2) various types of measures are explored, and there is an increased awareness of the potential programmes of measures where prevention, protection, preparedness, and recovery and review measures are combined. Steps towards the integration of flood risk management with nature, environment and water-quality objectives by multiple use of the same data sets have been made but can be further improved.

All Member States are — for the first time — concurrently taking action, under the same framework, to prevent or reduce social, economic and environmental damage from flood risk. The detailed information from the FHRMs should direct decision-makers and authorities towards (programmes of) measures aimed at reducing flood risks in an effective and sustainable way for the aquatic environment and for societies (EC, 2015c).

4.2.2 Links between the Floods Directive, the Water Framework Directive and the Birds and Habitats Directives

The Floods Directive is linked to the WFD in all stages of the planning cycle, from problem identification to implementation and monitoring. The main benefits of this mutual coordination are the improved efficiency when communicating with the public, better information exchange between those working on floods and water (quality) management, and achieving common synergies in the environmental objectives of the Floods Directive and the WFD (EC, 2014d).

These commonalities are not an end point, as there is room for further improvement (EC, 2012d). Part of the current implementation gap in the WFD can be attributed to challenges that are linked to flood risk management. First, the cost-effectiveness of the programmes of measures is not always clear and it can be assumed that it is difficult to attract funding for large-scale restoration projects. Second, there is a lack of integration and coherence with other policy domains, including the CAP and regional and urban policies. And, third, it is necessary to improve governance, among other things, by addressing ineffective water planning and management in order to tackle coordination problems (EC, 2012b).

The Floods Directive is related to EU nature legislation by the requirement to include protected areas in the flood risk maps (EU, 2007, Art. 6 §5(c)) and by a specific mention of the need to take into account nature conservation in the FRMPs (EU, 2007, Art. 7 §3). The Floods Directive also recognises the opportunities created by giving rivers more space through the maintenance or restoration of floodplains in flood risk management.

Through the links to the WFD, all activities under the Floods Directive must be in line with the requirements of the Birds and Habitats Directives as well, for example, when flood-protection measures potentially affect one or more Natura 2000 site (EU, 1992, Art. 6). The Floods Directive, from 2007, came after the WFD and the Birds and Habitats Directives and obviously refers to these other policies. However, to come to a mutual understanding and synergies between water and nature policies, the objectives and working methods of the Floods Directive should be taken into account when developing actions under the WFD or the Birds and Habitats Directives.

Neither the WFD nor the Floods Directive change any of the requirements for the Birds and Habitats Directives, but they provide a joint framework for the implementation of measures in water-dependent Natura 2000 sites (EC, 2011c). Therefore, it is recommended that water bodies, as the basic unit for the WFD, are delineated as far as possible, taking into account the protected areas from the Birds and Habitats Directives, because these protected areas introduce additional objectives (EC, 2003). As one of the steps to help achieve this, a recent study explores the possibilities of linking the available information from WFD and HD on water bodies, habitats, status, pressures and measures (ETC/ICM, 2015a). The restoration of healthy ecosystems (e.g. through Natura 2000 networks), can be a very effective way of preventing and mitigating floods, and will in addition be an important tool in adapting to climate change. However, mismatches between the directives can occur as well. These can be solved by early cooperation, negotiation and well-informed choices using the flexibilities that the directives provide (Summary Report, 2015).

In the 2014 workshop on the coordinated implementation of nature, biodiversity, marine and water (NBMW) policies (Workshop preparatory committee, 2014), it was stressed once more that successes in water, nature (or marine) policies invariably depend on the progress in all other areas. A coordinated implementation is rewarding, as the joint implementation of water and nature policies achieves higher quality outcomes for our environment and promotes better regulation at European and national level, including avoiding burdensome duplication of work (Workshop preparatory committee, 2014). There are no objective obstacles that prevent us from working together efficiently and exploiting the synergies of NBMW policies, as there is no essential contradiction in objectives between them. Nevertheless, a full harmonisation is not possible (Summary Report, 2015).

Notwithstanding the different contexts in which the Birds and Habitats Directives, the WFD and the Floods Directive are developed, and the different objectives they aim to achieve, which create different instruments, there are plenty of good examples on a more coordinated approach of the policy processes, for example, on monitoring and reporting and on the development of programmes of measures and public consultation (Workshop preparatory committee, 2014). Table 4.1 presents a comparison of some management aspects, indicating similarities and differences between the Floods Directive, the WFD and the Birds and Habitats Directives. Examples of potential synergies and conflicts at different scales, related to hydrology and physical processes, can be found in Table 4.2. The importance of potential conflicts becomes clear when assessing the state of Europe's nature: besides agriculture, the modification of natural conditions of water bodies is seen as a major pressure, and pollution remains an issue (EEA, 2015f). The proportion assessments which are unfavourable and deteriorating are particularly high for species and habitats associated with wetlands, alluvial grassland, riparian forests and freshwater (EEA, 2015f).

There was a large consensus that there is a need to further define a common agenda, building further on the basis of the NBMW workshop (Summary Report, 2015). A follow-up event under the Luxembourg Presidency took place in November 2015 to further progress the common agenda.

Table 4.1 Comparison of some management aspects of the Floods Directive, Water Framework Directive and Birds and Habitats Directives

Directive(s)	Floods Directive	Water Framework Directive	Birds and Habitats Directives
Objectives	Assessment and management of flood risk Reduce adverse consequences (human health, the environment, cultural heritage and economic activity)	Good status (ecological and chemical status for surface water, chemical and quantitative status for groundwater) No deterioration Exemptions	Favourable conservation Status of protected habitats and species No deterioration
Scale	River Basin District (Unit of Management) Areas of Potential Significant Flood Risk Country	River Basin District (and sub-units) Water body and water body types specified at biogeographical scale Country	Biogeographical region, country, site Habitat type Species
Instruments	Preliminary Flood Risk Assessment Flood Hazard and Risk Maps Flood Risk Management Plan	River Basin Management Plan Programmes of Measures Normative definitions (type, reference, intercalibration)	Network of Protected Areas for Habitats/Species (Natura 2000) Habitats and wild fauna and flora Appropriate Assessment Management Plans
Schedule	6-year management cycle ending 2015, 2021, etc.	6-year management cycle ending 2015, 2021, etc.	6-year reporting cycle ending 2012, 2018, etc.

Source: Based on Workshop preparatory committee (2014) for Birds and Habitats Directives and Water Framework Directive objectives and scale.

Table 4.2 Links and potential synergies between the Floods Directive, Water Framework Directive and Birds and Habitats Directives

Column A	Column B	Column C	Column D	Column E
Scale	Hydrological processes of interest for the Floods Directive	Physical processes which are of interest for the Water Framework Directive and which have a relation to the hydrological processes in Column B	Physical processes which are of interest for the Birds and Habitats Directives and which have a relation to the hydrological processes in Column B	Potential synergetic measures between Columns B, C and D
Catchment	Infiltration Retention Storage	Nutrient control Natural hydromorphology of small water bodies ([a])	Groundwater in- and out-flow Natural groundwater level fluctuations Temporal pluvial and groundwater floods in low-lying areas	Restoration of buffering capacity of agricultural land and forests Natural Water Retention Measures Land use planning, securing functions and ecosystem services
Floodplain/ Areas of Potential Significant Flood Risk	Storage Attenuation of flood waves (upstream stretches) Increase of discharge capacity (downstream stretches)	Nutrient-retention Natural hydromorphology of water bodies in floodplains ([a])	Connectivity in natural degrees Continuity Inundation depths at natural levels Natural erosion and sedimentation processes	Increasing or reactivating floodplains Land use planning, excluding certain developments, keeping storage / discharge capacities intact Increase floodplain area Protection of Natura 2000 from adverse effects of flood risk management Green infrastructure to support multifunctionality
River bed	Fast discharge of flood water	Natural hydro-morphology ([a])	Continuity Environmental flow	Sediment management

Note: ([a]) Hydromorphological elements supporting the biological elements: hydrological regime, quantity and dynamics of water flow, connection to groundwater bodies, river continuity, morphological conditions, river depth and width variation, structure and substrate of the river bed and structure of the riparian zone.

4.2.3 Potential conflicts with thematic policies

Without diminishing the importance of reaching the 'good' status for all water bodies in Europe and a sustainable flood risk management, it is clear that many other EU (environmental) objectives use the same (scarce) resources (i.e. water and the adjacent land areas); for example, to secure food production, fertile arable land is needed; to reduce carbon dioxide emissions, renewable energy needs increase and less fuel must be used per tonne and kilometre of goods transported.

The Renewable Energy Directive (EU, 2009), which includes hydropower, and the White Paper on transport (EC, 2011e), which promotes the integration of inland waterways into the transport system in their support for multimodal transport, are two examples of thematic policies that aim to improve Europe's environmental quality, and that therefore potentially conflict with the aims of the WFD, the Floods Directive and the Birds and Habitats Directives. A successful implementation of all these agendas is possible only when there is a sufficient level of coordination and cooperation. Among the tools available to encourage a more integrated approach — linking socio-economic issues with environmental aspects — are the Strategic Environmental Assessment (SEA) Directive (EU, 2001) and the Environmental Impact Assessments (EIA) Directive (EU, 2012b, 2014a).

Agriculture

Under the rural development policy of the EU (Pillar 2 of the CAP) are two development priorities defined as being of direct relevance for water-quantity and flood risk management (EU, 2013c):

- restoring, preserving and enhancing ecosystems: improving water management, including fertiliser and pesticide management (Priority 4b); and
- resource efficiency and shift towards a low-carbon and climate-resilient economy: increasing efficiency in water use by agriculture (Priority 5a).

Under these priorities, measures affecting the occurrence, timing or extent of flooding can be included and this encompasses both the floodplain and the wider catchment.

The most common example in the floodplain is the promotion of land use changes that reduce the hydraulic resistance. In the catchment this can be done by promoting land use modifications that increase infiltration and delay run-off (e.g. by adapted cropping patterns or reforestation). Alternatives are the provision of additional or reinforced ecosystem services (e.g. by allocating parcels for water storage during floods) or by taking water conservation measures.

The effects of measures in the floodplains are more likely to be directly visible. The effect of measures taken in the catchment will, to a large degree, depend on the spatial scale of measures compared with the catchment area. Furthermore, such measures can have a long lead time before their effects can be demonstrated in hydrological measurements.

The Rural Development Programmes (RDPs) ([16]) 2014–2020 are very relevant for water management, as they define largely how agriculture pressures will be addressed in the River Basin Management Plans (RBMPs) to be made available by the end of 2015. In addition, the RDPs represent 20 % of the CAP budget. However, integration of the two fields remains difficult in practice.

The draft RDPs were screened with regard to their efforts to contribute to the ecological functioning of water bodies, taking into account the flood-protection requirements. In addition, how they align with the WFD implementation and contribute to the restoration of water bodies was checked (Fresh Thoughts Consulting, 2014). In many of the RDPs there is an emphasis on hard defences such as dykes and reservoirs, rather than on giving priority to NWRMs. Explicit references to maintain and not degrade are scarce and so are the links to the Floods Directive (Fresh Thoughts Consulting, 2014). Although there is improvement in the adopted RDPs compared with the draft versions it — in general — remains a missed opportunity to strengthen the links between CAP and water policies. It has been noted that sector-specific policies such as for agriculture tend to require greater land and water use (Zandstra, 2015). Although the revised CAP includes measures to reduce water use in agriculture, the decision to add the WFD to the list of issues subject to cross-compliance was postponed.

Hydropower

An overview of the impacts of hydropower generation on water management can be found in the report 'Towards efficient use of water resources in Europe' (EEA, 2012c). The impacts are many and can result in altered flow regimes and water-level fluctuations as well as in sediment transport and retention in floodplains (EEA, 2012a). The Renewable Energy Directive (EU, 2009) does not set legally binding national targets for hydropower specifically but does so for electricity and transport for renewable sources in general. Where this directive makes a general reference to ecosystem services and the Ramsar Convention (Ramsar Convention Secretariat, 2014) in the preambles, there is no specific reference to the WFD or any other specific European water or nature legislation. Whereas most RBMPs in the first cycle of implementation of the WFD (by 22/12/2009) do not make a reference to the exemptions for the environmental objectives (EU, 2000, Art. 4 §7) there seems to be a lack of integration between water and energy policies (EC, 2012d). Nevertheless, there are several examples of sustainable hydropower development, including in Austria (Koller-Kreimel, 2015) where a catalogue for water protection and use sets national criteria for new hydropower projects (BMLFUW, 2012) and was developed in cooperation with nine regional governments and stakeholders. In addition, for the Danube River Basin, guiding principles are adopted (ICPDR, 2013), with attention given to both existing and newly developed power plants. However, up to the present, both the water sector and the energy sector are at risk of failing to achieve the objectives and legal compliance without a cross-sectoral dialogue (Mair, 2015).

Inland navigation

NWRMs and giving room to rivers and other flood risk management measures working with natural processes may influence flow patterns (and

([16]) A total of 78 out of 118 RDPs are adopted, covering 76 % of the EU rural Development Funds (Status as of 25/08/2015), http://ec.europa.eu/agriculture/rural-development-2014-2020/country-files/common/overview-map-adopted-rdp_en.pdf, accessed 16 November 2015.

erosion-sedimentation processes) during normal conditions, and these projects often aim at increasing the biodiversity. This may have an impact on inland water transport (PIANC, 2009). Measures taken for the benefit of navigation can be divided into:

- maintenance measures, such as extractive dredging, sediment feeding and management or vegetation maintenance;
- construction measures, like groynes, dykes and revetments, sills and armoured layers, rock blasting, locks and barrages or flow regulation;
- operational measures, like terminal and port facilities, or river information services (PIANC, 2009).

Where the maintenance and operational measures in general affect the physical characteristics of the flood wave only to a limited extent, it is also true that maintenance measures such as extractive dredging, sediment management or vegetation management can have significant effects on the ecosystem services in the riverbed and floodplain. This is even truer for construction measures for navigation, and, in addition, they may influence the probability, magnitude and duration of flooding. Construction of levees and flow diversions have the greatest impacts on ecosystem services, but they can be reversed more easily (e.g. by dyke-openings) than modifications of the river itself (PIANC, 2009).

However, it needs to be mentioned that of the many grey river engineering measures reducing the natural storage of floodwaters, only some of the developments can be attributed to navigation, mainly:

- river regulation that causes an increased flood wave propagation which is leading to increased flooding downstream; and
- excessive levee construction or channelling that accelerates flood peaks and wave heights (PIANC, 2009).

Although developed originally within different communities, ecosystem-based flood risk management and navigation needs are not incompatible. A joint statement for the river Danube (ICPDR, 2007) was made based on integrated planning, defining goals and ensuring comparability of alternatives, applying EIAs and with respect for and contributing to the RBMPs (Mair, 2015) and further specified in a manual (ICPDR, 2010) and with a yearly follow-up and exchange of good practice. To maximise synergies between transport needs, WFD, Floods Directive and Birds and Habitats Directives, also in terms of (co-)funding, an integrated planning approach is necessary (e.g. by integrating river restoration initiatives into inland water transport sector plans) (EC, 2012e).

4.2.4 Environmental assessments

The Strategic Environmental Assessment Directive (SEA) (EU, 2001) aims to encourage a more integrated and efficient approach to territorial planning where environmental considerations, including biodiversity, are taken into account much earlier on in the planning process and at a much more strategic level. This should lead to fewer conflicts further down the line at the level of individual projects.

A SEA is mandatory for a variety of plans and programmes dealing with land use changes including for agriculture or forestry, energy, or water management. A SEA should also be carried out on any plan or programme, which, in view of the likely significant effect on sites, has been determined to require an assessment pursuant to the Habitats Directive (EU, 1992, Art. 6 §3).

A SEA sets the framework for the future development consent of projects listed in the Environmental Impact Assessment (EIA) Directive (EU, 2012b, 2014a). Although the SEA process operates at the level of plans and programmes, the EIA Directive operates at the level of individual public and private projects. Therefore, development consent for projects ([17]) that are likely to have significant effects on the environment should be granted only after an assessment of these likely effects has been carried out.

Flood relief works in general are not among the projects for which an EIA is mandatory. They do, however, require screening by Member States, in order to decide about the necessity of an EIA. For dams and reservoirs, which may play a part in flood control, an EIA is mandatory. In addition, for many types of projects that may cause negative environmental impacts as a consequence of floods, such as the construction of oil refineries, chemical installations, power plants and quarries, an EIA is mandatory.

Flood risk-reduction measures to be implemented as part of the currently devised FRMPs are therefore likely to require screening and potentially a SEA or EIA, the results of which are to be included in the FRMP. In such cases, the two may profit from each other's

([17]) The jurisprudence of the Court in relation to the concept 'project' is summarised in (EC, 2015e).

databases and public consultation processes. The drafting process of a SEA or EIA may raise awareness of potential adverse environmental impacts of proposed FRMP measures and foster a creative process to devise better-balanced measures.

4.3 Flood risk management, climate change adaptation and disaster risk reduction

Besides the specific links between water and nature policies on the one hand and thematic policies such as the CAP, energy (hydropower) or transport on the other, there are also cross-cutting issues that need special attention as they — by their very nature — have an impact on all activities. To take them into account is a prerequisite for a successful integrated planning between involved different policy domains.

4.3.1 Climate change and adaptation in European directives

In Europe, policies for adaptation to climate change have been developed at many levels: from a local to a European-wide scale. There is limited systematic information on current implementation or effectiveness of adaptation measures or policies. Some adaptation planning has been integrated into coastal and water management, as well as disaster risk management (IPCC, 2014b, Chapter 23: Europe). A Europeanwide state of play for adaptation activities on a national scale is presented in (EEA, 2014c)

Water Framework Directive and the Water Blueprint

Climate change and adaptation are not mentioned explicitly in the WFD (EU, 2000). Nevertheless, future climate change scenarios were mentioned in almost 70 % of the first RBMPs in 2009 (EC, 2012a). The four most often cited climate change threats are: flooding, changes in water demand and availability, threat of drought, and impacts on water-quality and biodiversity.

The subject has been discussed intensively over the past years as climate change pressures are exacerbated by human and economic activities and climate change poses an additional threat to the flow regime of water ecosystems (EEA, 2012b).

The step-wise and cyclical approach of river basin management described in the WFD makes the process well suited to adaptively manage climate change impacts (EC, 2009). Climate-related threats and adaptation planning should be incorporated in the RBMPs from the second planning cycle (for WFD 2009–2015) onwards. As a minimum it should be demonstrated how climate change projections have informed the assessment of pressures and impacts, how the monitoring programmes are configured to detect climate change impacts and how selected measures are robust to projected climate conditions (EC, 2009).

The Water Blueprint Communication (EC, 2012d) reviewed the most important water policy processes in the light of resource efficiency, including the water-related part of Europe's climate change vulnerability and adaptation policy (EEA, 2012c). In the Blueprint, climate change, as well as land use and economic activities, are depicted as the main causes that have a negative impact on Europe's water status. Adapting to climate change and building resilience to disasters are presented as key activities for a sustainable water management and good qualitative and quantitative status for water bodies in Europe and worldwide. The Blueprint communication explicitly refers to the (by that time upcoming) EU adaptation strategy (EC, 2013c).

Floods Directive

The effect of climate change on flood risk is still uncertain, but for one specific climate scenario, being the A1B scenario ([18]), roughly two-thirds of the modelled increase is attributable to economic growth and one-third can be attributed to climate change by the middle of this century (Jongman et al., 2014).

In the PFRA reporting in the first cycle of implementation of the Floods Directive (EU, 2007), only one-third of Member States explicitly considered climate change or socio-economic changes as long-term developments. This surprised the assessors, based on the substantial increase of flood losses in Europe over decades owing to increasing wealth located in flood-prone areas and climate change (EC, 2015c). However, from only the second cycle of implementation onwards (2016–2021), it is mandatory to include the likely impact of climate change in the PFRA.

([18]) The A1B scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies based on a balance across all energy sources. This balance is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies (IPCC, 2000).

Photo: © André Künzelmann/UFZ

The climate change impacts mentioned in the PFRA so far are mainly changes in precipitation and, to a lesser extent, changes in temperature, sea-level rises, increase in extreme events and changes in run-off. Changes in snowmelt, wind direction and wind speed and surface flow are mentioned for only a few UoMs.

For the FHRMs, no explicit reference to climate change is made in the Floods Directive. However, in the reporting guidance (EC, 2013a) a summary text on the methods used to include climate change in the FHRM scenarios can be reported as optional information.

FRMPs are due to be produced by the end of 2015, including a programme of measures. The likely impact of climate change on the occurrence of floods has to be taken into account, but for the review of FRMPs only. Strictly speaking, therefore, the Floods Directive does not ask for it in the first cycle of implementation. At least from the screening of the draft, climate change either do not seem to be fully considered or it is unclear if it is taken into account (WRc, 2015).

The shifts in the extremes, rather than the trends in the averages, are likely to be the biggest challenge for adaptation (EEA, 2012d; IPCC, 2012) and are likely to be the cost drivers for adapting the infrastructure (OECD, 2013). Although the strategies for disaster risk management developed within the context of climate change require measures that are specific to the local circumstances, including sustainable land-management and spatial planning (IPCC, 2012), the river basin approach avoids passing on negative consequences further downstream and for international RBDs for both the WFD and the Floods Directive, relevant information must be exchanged and the plans must be coordinated. Transboundary river basins pose especially complex challenges to building adaptive capacity.

Nature legislation

While in the Birds and Habitats Directives (EU, 1992, 2010) climate change and adaptation are not mentioned at all, it has a strong presence in the Biodiversity 2020 strategy (EC, 2011a). Although climate change is not having a major impact at present, it is expected to have an increasing impact in the future. Nevertheless, climate change is relatively infrequently reported as a pressure or threat in the 2007–2012 Habitats Directive Article 17 reports (in 3 % of habitat and 2 % of Member State species assessments it is reported as a pressure, and in 5 % and 4 %, respectively, as a threat) (EEA, 2015f).

Adapting the Natura 2000 network to climate change based on current policy requires voluntary action by the Member States, which may not be timely or ambitious enough (Verschuuren, 2010). A targeted guidance document specifically on climate change and Natura 2000 was published, to optimally address the impacts of climate change in managing the network's protected sites (EC, 2013f).

4.3.2 *Socio-economic change, land use change and spatial planning*

Flood risk management is related to socio-economic development by two mechanisms. The first and most important mechanism is that, as a result of socio-economic development, the economic value of the assets in floodplains increases. This in turn increases the justifiable investments for protection measures.

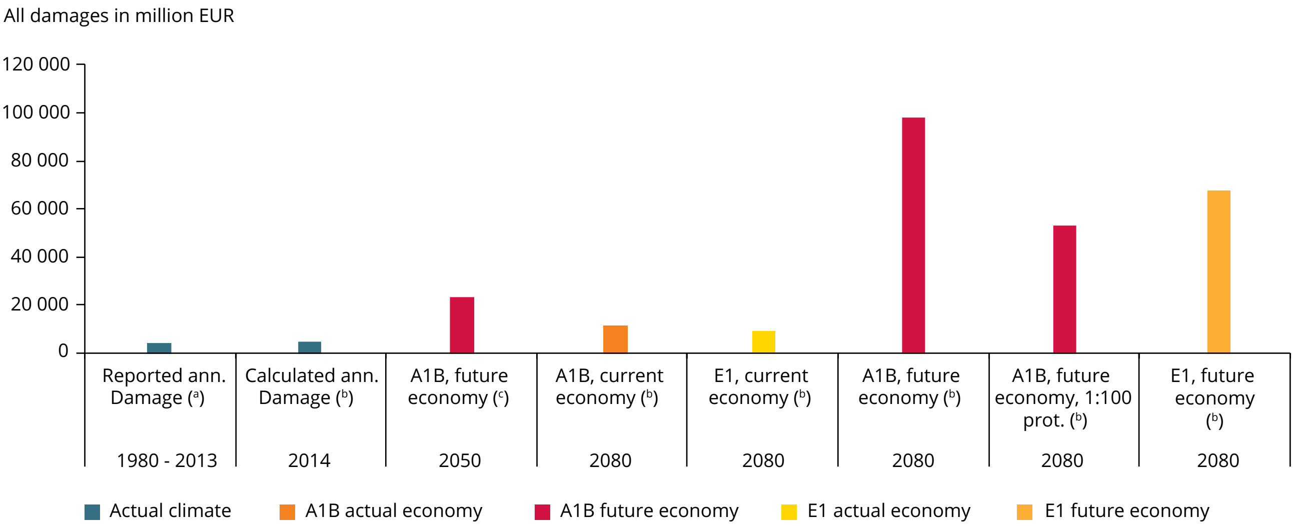
Figure 4.3 presents recent estimates of calculated future flood losses. With all the uncertainties inherent in these data, the picture is clear that flood losses can be expected to increase fivefold by 2050 and up to 17-fold by 2080. The major share of this increase (70–90 %) is attributable to socio-economic development, and the remainder (10–30 %) to climate change (Ciscar et al., 2014; Jongman et al., 2014).

The second mechanism is that the change in land use that results from socio-economic development may lead to changes in the hydrological characteristics of a catchment, which in turn may cause an increase in peak floods. This effect, however, is difficult to demonstrate in real data and becomes significant only in small catchments with large-scale changes in land use.

The methods to quantify socio-economic changes, such as urban sprawl and soil sealing land use and, in particular, their potential future impacts on water management, should be further improved (EC, 2015c). Whether or not land use change significantly affects flood risks depends first on the location of the land use change. Land use changes in floodplains have a direct impact on flood risk because they affect the invested values at risk, and they may also increase water levels during floods. The effects of changes in the wider catchment depend on the scale of changes relative to the scale of the catchment (e.g. ICPR, 2006).

Guiding land use change can, at least in theory, be realised by spatial planning policies. However, spatial planning is not subject to EU regulation, except at sea under the Maritime Spatial Planning Directive (EU, 2014b). In practice, the implementation of planning policies is often incomplete owing to a lack of specific instruments and measures (Mickwitz et al., 2009; Swart et al., 2009; IPCC, 2014b, Chapter 23). In addition, spatial planning and water management have for a long time been viewed as separate management problems (EEA, 2012d), where the interests of flood risk management are sometimes valued lower than those of competing economic functions such as agriculture (see also Box 4.5), housing (ARUP, 2011) or infrastructure.

Figure 4.3 Annual flood losses for 2050 and 2080 compared with the 'actual situation'



Note: For SRES scenarios A1B and E1 and for current and future economies. The SRES scenarios cover a wide range of the main driving forces of future emissions, from demographic to technological and economic developments (IPCC, 2000; van der Linden and Mitchell, 2009).

1:100 prot.: to be understood as a protection against the flood with a 1 % annual probability for the future climate everywhere in place.

Sources: ([a]) EEA, 2015a; ([b]) Ciscar et al., 2014; ([c]) Jongman et al., 2014.

At European level there is no policy instrument in place to organise a process to signal the effects that land use changes may have on flood risk management or water body status and to take mitigating measures in a timely manner. This could be a role of the SEA and EIA Directives (see Section 4.1.4).

4.3.3 Financing instruments

River restoration and flood risk management projects are mostly financed from national funds. With public funding under pressure (e.g. EC, 2012d; Despotovic, 2015; EEA and ETC/ICM, 2015; Morse, 2014), there is a tendency within at least some of the competent authorities to focus their spending on their core tasks (i.e. flood-protection). An example is the Dutch flood-protection programme (Hoogwaterbeschermingsprogramma, 2013), which subsidises only 'sober and efficient' protection measures. As a result, the additional investments required to implement integrative measures rather than sectoral measures are not directly or fully covered by national funds and additional funding by other stakeholders (e.g. non-governmental organisations (NGOs), national or local authorities) can be required.

Innovative ways that may help to cover these expenses are Payment for Watershed Services (PWSs) and Water Funds. PWSs belong to the wider category of Payments for Ecosystem Services and are voluntary mechanisms to maintain or enhance the provision of ecosystem services (EC, 2015i). Water Funds are innovative ways to finance water management, to ensure the supply of environmental services from a healthy watershed and promote integrated and participated watershed management based on a long-term work plan (EC, 2015i).

At EU level, the EU-LIFE programme is the EU's financial instrument to support environmental, nature conservation and climate action projects throughout the EU. At the end of 2014, searching in the LIFE project databases with the keyword 'wetland', which includes floodplains, highlighted 239 projects, and with the keyword 'aquatic ecosystems', where riparian zones and floodplains are an integral part, highlighted 54 projects. The new LIFE+ Integrated Projects offer funding possibilities for nature-based solutions and NWRMs.

A core issue in these solutions is that a stronger case than is presently available is needed to underpin the cost-effectiveness of integrative nature-based solutions. The ecosystem services approach is an important instrument in this respect, but cases based on 'willingness to pay' are not considered strong enough to hold in court (EEA and ETC/ICM, 2015); although in other cases, this approach has been welcomed by policymakers for making such services visible. Promising services are those that lead to cost savings in flood-protection and drinking water treatment (Zandstra, 2015). Building stronger cases will not only be instrumental in attracting funds, but also and in parallel, in building up institutional and public support.

Although most of the nature-based solutions for flood risk management can be found in the measures for preventing and protecting against flooding, which are necessary to reduce overall flood losses, the Floods Directive also focuses on preparedness, with (often non-structural) measures such as flood forecasting and flood warning. However, one should not forget that — as total protection does not exist — financial instruments also need to be in place for the response and recovery phases (during and after a flood). Because people and their goods are threatened, decisions have to be taken under high uncertainty and time pressure, and decision-makers often pay less attention to ecosystem services or nature-based solutions. Their scale of applicability ranges from international solidarity (e.g. the EU Solidarity Fund; see Box 4.2) or State Aid under very specific conditions (EU, 2012a, Art. 107) ([19]), to individual initiatives (such as flood insurance; see Box 4.3).

4.3.4 Governance

The available evidence of the progress made in the implementation of both the WFD and the Floods Directive indicates that governance-related issues will need continuing attention. According to the EU Strategy on Adaptation to Climate change (EC, 2013c), an important challenge is in coordination across the various levels of planning and management. A similar hint can be derived from the screening of the draft RBMPs and FRMPs, provisional as they are. The screening states that international coordination seems to lag behind, that coordination of the setting of objectives has been achieved in fewer than half of the UoMs investigated, and that public consultation on these objectives took place in only a little over half of the RBDs or UoMs (WRc, 2015). These numbers may improve in the final reporting for 2015, but for the

([19]) See also the upcoming EEA report on Climate change, impacts and vulnerability in Europe 2016 for a more detailed discussion about the damages caused by weather and climate extremes.

Box 4.2 The EU Solidarity Fund

In the aftermath of the exceptional floods along the Elbe and Danube rivers in August 2002, the EU Solidarity Fund (EUSF) was set up as a new EU financial instrument. The EUSF was established in an unusually short time and equipped, over and above the ordinary appropriations in the Multiannual Financial Framework (MFF), with up to EUR 1 billion annually.

Since 2002, the EC has taken major steps to make the EUSF more responsive and applicable for a broader scope. A new proposal, to reform the EUSF, was presented in July 2013. It is less ambitious and more acceptable to EU Member States than previous suggestions that did not pass the European Council. The new MFF (2014–2020) halved the annual ceiling of the EUSF but set its limit at a constant 2011 euro value (EU, 2013b). The administration of the applications was also simplified. As before, the EUSF can be used for national and regional natural disasters and for neighbouring countries affected.

By choosing to reinstall the absolute damage threshold criterion of EUR 3 billion in 2011 instead of 2002 prices, the legislator made it easier for the largest (six) EU economies to access the post-disaster solidarity aid, while the relative threshold of 0.6 % of the Gross National Income remained unchanged. The reform of the EUSF has made a clearer definition of the terms under which solidarity aid can be provided for regional natural disasters, causing damage below these thresholds but disproportionally affecting the regional economies. The initially unspecified regional dimension has been equated with the second level statistical subdivisions in the Nomenclature of Territorial Units for Statistics (NUTS2) which in many but not all EU Member States tallies with the administrative division.

For flood-related disasters only, the total damage registered since 2002 amounted to EUR 51.5 billion (2014 euro prices). Around EUR 2.1 billion (approximately 50 % of the total EUSF resources) has been mobilised to assist a total of 18 countries to cope with the impacts of floods. Only EUR 417 million (approximately 20 % of the total aid) has been disbursed for events other than major events. The countries affected by the 2002 and 2013 central European floods (Austria, Czech Republic and Germany) are among the largest recipients of the EUSF, followed by the United Kingdom, which applied only once for the aid from the EUSF in the aftermath of the 2007 floods.

The EUSF has attracted little attention in scientific literature. The legitimacy, viability and efficiency of the fund has been analysed using normative and quantitative assessment criteria (Hochrainer et al., 2010). Focusing on flood risk only, and assuming spatial independence of the risk, there is a probability of 8 % that solidarity aid claims will exceed the annual ceiling (for all disbursement of the EUSF meant to cover all hazards), which at the time was set to EUR 1 billion. So even if dedicated entirely to post-flood disaster assistance, the EUSF would be depleted without covering all solidarity assistance quests every 12 years on average (this probability increases to 10 % for the maximum case). A significant and positive correlation between flood probabilities in 63 % of 1 007 European sub-basins has been found (Jongman et al., 2014). The authors estimated that the annual average demand for the EUSF's assistance would amount to EUR 258 million and the probability that the fund would be depleted without satisfying all claims would amount to 5 %. The latter would increase to 9 % as a result of projected climate change until 2050.

Box 4.3 Flood insurance

Flood risk transfers and insurance positively influence recovery and reconstruction. However, of all hydrological hazards (flooding and wet landslides) over the period 1980–2013, only around one-third were insured. This proportion is similar when compared to impacts from storms and is higher than all other natural hazards (EEA, 2015a).

The insurance and banking sectors face problems relating to the accurate pricing of risks, the shortage of capital after large loss events, and an increasing burden of losses that can affect markets and insurability, within and outside the European region (Botzen et al., 2010). Sound knowledge of flood risk is essential for designing viable risk-sharing schemes (Jongman et al., 2014). At present, compensation mechanisms are focused on the financial losses after an event rather than reducing the underlying flood risks. Nevertheless, risk pricing can be designed so as to include incentives for individual risk reduction (Surminski et al., 2015). Public interventions can stimulate the market penetration of flood insurance and attend to insurance affordability. Government intervention is, however, often needed to provide compensation and financial support in the event of major losses (Aakre and Rübbelke, 2010).

The 'Green Paper on the insurance of natural and man-made disasters' (EC, 2013e) initiated a discussion on the role of the EU in promoting individual and collective resilience to natural hazard strikes. So far, the EC has not stated whether and how it intends to use the results of the consultation in order to promote a greater uptake of flood insurance throughout Europe (Surminski et al., 2015). The European Parliament made a critical review of the Green paper and concluded that disaster insurance harmonisation is not prudent because insurance should remain voluntary and the market should be as flexible as possible to come up with products tailored to local requirements (EP, 2014).

moment there seems to be a discrepancy between the generally accepted benefit of early involvement and the apparent late reporting on public participation (WRc, 2015).

The NWRM report on policy coordination (EC, 2014c) paints a varying picture of governance arrangements for the WFD (which also affects NWRMs), stating that in many countries the structures for the WFD implementation built on the existing structures. As these were different across the EU before the WFD, they have remained different until now. As some governance-related elements are shared between the Floods Directive and the WFD, such as appointing competent authorities, defining UoMs, organising public participation, or ensuring international coordination where appropriate, governance offers potential synergies between the two.

In addition, the Intergovernmental Panel on Climate Change identifies weaknesses in present governance arrangements, such as a lack of concrete instruments beyond a general level of policy formulation and a lack of institutional frameworks to support (climate) adaptation (IPCC, 2014b).

From experiences in France, Germany, the Netherlands, Poland, Romania, Sweden and the United Kingdom, one can conclude that the Floods Directive is implemented differently across the EU, and even within one country (van Eerd et al., 2015; Głosińska, 2014; Hartmann and Spit, 2015; Hedelin, 2015; Heintz et al., 2012; Vinke-de Kruijf et al., 2015). Five more general issues for implementing the Floods Directive were identified:

1. Capacity: the Floods Directive introduces new tasks to governmental organisations. Their capacities may not be up to these tasks, such as: thinking in a river basin perspective, designing space for the river measures, mapping flood risks, engaging with stakeholders.

2. Timing: the tight deadlines of the directive are seen as a mismatch with implementation of the ambitious aim to change from flood control to flood risk management.

3. Vertical coordination: the directive requires coordination across national and regional authorities, but this is not necessarily in place or the responsibilities are not well defined.

4. Stakeholder engagement: stakeholder engagement is necessary for implementation and support of local actors, yet remains difficult to put into practice.

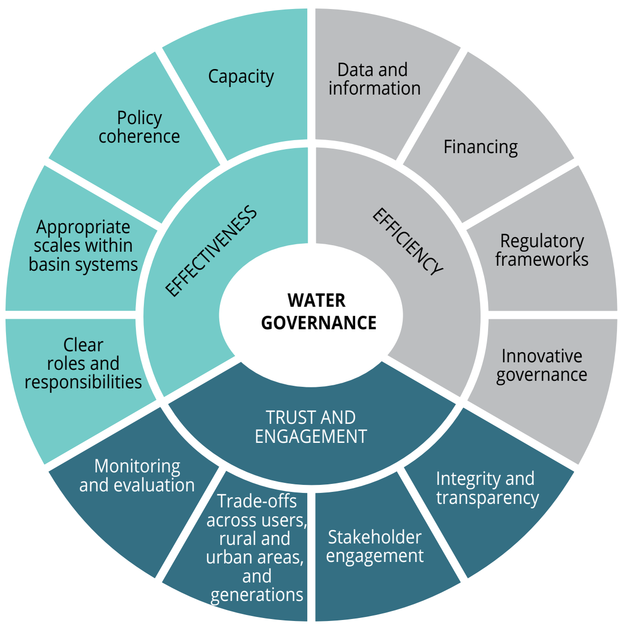
5. Institutional change: depending on its ambitions, where a region has to change its flood policy and depending on its current institutional structure, where changes in institutions and legislation are required to implement the Floods Directive.

The Organisation for Economic Co-operation and Development (OECD) recently developed a tool for the analysis of governance arrangements (OECD, 2015), which gives a complete list of elements to be taken into consideration. Figure 4.4 represents a summary overview; for further explanation, see the source document.

Figure 4.5 shows the links between the Floods Directive and the WFD with respect to public participation. Key success factors for public participation in water management, and its relation with the wider governance in water management, is presented in a recent EEA report based on eight case studies (EEA, 2014e). Synergy in public participation and information exchange may also be found with the Seveso III directive (EU, 2012c) which puts much emphasis on providing information to the public.

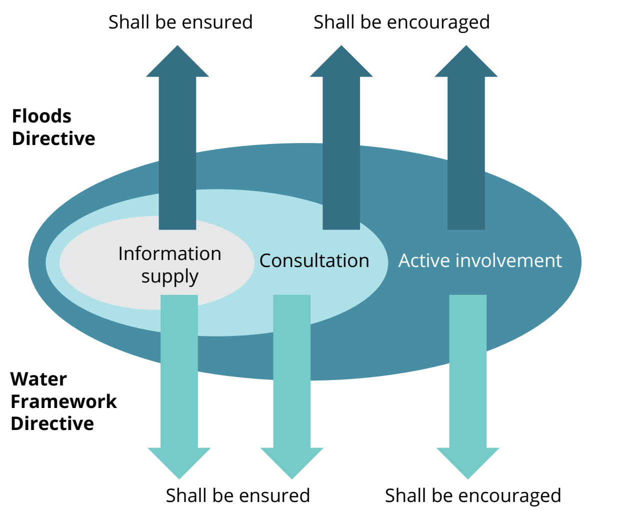
Evaluation of the public participation process for the Floods Directive — which should encourage active involvement of interested parties for the FRMP, while ensuring that the PFRA, the Areas of Potential Significant Flood Risk and the FHRMs are simply 'made available' to the public — is not yet considered.

Figure 4.4 Overview of governance principles



Source: OECD, 2015.

Figure 4.5 Levels of public participation in the Floods Directive and Water Framework Directive



Source: EC, 2014d.

A joint approach for WFD and Floods Directive may prove beneficial. The evaluation must include a clear definition of the goals of the process. These are formulated in the Floods Directive, but also other more generally stated objectives, for example as formulated in the case studies (EEA, 2014e) or by OECD (Buckle, 2015), may be included.

How the different governance principles are combined into a specific governance model depends on the local situation: the key issues (and most important links to other activities and legislation), the stakeholder composition, previous experiences, administrative set-up, etc. The governance principles were used in interviews with experts from two European river basins, the Guadiana and the Rhine (Boxes 4.4 and 4.5), questioning to what extent each of the principles is present in their river basin with regards to the Floods Directive implementation.

4.4 Gaps in knowledge and policy integration

Notwithstanding the detailed data and information available at local scale, which often cover a wide range of themes, there are gaps to be filled to ensure a better implementation of the Floods Directive and a more environmentally focused flood risk management.

4.4.1 Data

As seen in the reporting on past floods in the PFRA (and in the European database on past floods), data on the environmental impacts of floods are scarce. The subtypes of consequences foreseen in the reporting for the Floods Directive (affecting water body status, protected areas and pollution sources) (EC, 2013a) seem to cover the most important aspects with the exemption of a subtype on erosion and/or sedimentation.

Where floodplains are approximated by the areas with alluvial soil, wetlands, of the hydraulic floodplain for a given return period, it already becomes clear that data on delineations of floodplains are incomplete. At European scale, the data must not be as detailed as for the planning of measures and development of specific areas, but actual data availability does not allow a proper status and trends assessment of Europe's floodplains.

Two other data gaps are related to this one: detailed information on land use in floodplains and an overview of flood-protection measures. Although Europe has good spatial data on land use and protected areas such as CLC (EEA, 2014b), Natura 2000 (EEA, 2015d) or the Common Database of Designated Areas (EEA, 2014d) ([20]), the high-resolution data needed to estimate potential flood losses or changes in ecosystem services provided are not available, even with the CLC changes (EEA, 2014a) available on a more detailed scale.

In addition, information on flood-protection infrastructure is unavailable across Europe, and these linear infrastructures are not included in land use maps such as CLC. In most studies now carried out, in which most of Europe is covered, simple assumptions such as 'protection against a flood with a return period of 100 years in place' are used; these are updated with more detailed values where available but never include local variations (e.g. Ciscar et al., 2011; Jongman et al., 2014; Mokrech et al., 2015; Rojas et al., 2013).

Notwithstanding the large projects on the (methodologies for the) assessments of ecosystem services and attempts to quantify them in a global context, for example in the Millennium Ecosystem Assessment (2003) ([21]) or the economics of ecosystems and biodiversity (TEEB) (UNEP, 2010) or — on a European scale — in the Mapping and Assessment of Ecosystems and their Services (MAES process (EC, 2013g, 2014e), specific data to underpin the economic justification of measures, including benefits

([20]) For more data sets, see http://www.eea.europa.eu/data-and-maps/, accessed 16 November 2015.
([21]) See for an overview of reports, see http://www.millenniumassessment.org/en/Reports.html#, accessed 16 November 2015.

Box 4.4 Recommendations to implement the Floods Directive in the Rhine basin — a water governance perspective

Since the Floods Directive came into force, much has happened to implement it in the Rhine basin. The roles and responsibilities had to be allocated for the three implementation steps of making PFRAs, FHRMs and the FRMPs. Many of these tasks are carried out by the regional and local governments, whereas flood control used to be the responsibility of a national government. The implementation process is going well: discussions are taking place on new strategies to change from flood control to managing flood risks; maps are prepared at the local level, resulting in an improved understanding of the local flood risk situation; Member States are pushed to be transparent when they engage with stakeholders and present their FRMPs.

However, there are also issues that require attention for the next six-year implementation cycle of the Floods Directive. These issues are discussed and complemented with lessons learnt from the Room for the River programme (the Netherlands), which implements over 30 projects that integrate flood control with spatial quality along the Dutch branches of the Rhine.

The first issue relates to transferring responsibilities to the regional and local governments. These governments do not always have sufficient technical capacity to develop flood risk management measures and maps. Moreover, public administration staffs are reduced across the river basin, making it difficult to conduct the required work for the Floods Directive. Insights from the Room for the River programme suggest that tasks should be matched with the expertise and capacity of an organisation rather than imposing new tasks on them. Integration across different levels of government is reached by initiating (and maintaining) region-specific Steering Committees where administrators of different levels meet. Another lesson is that responsibilities should not be well defined only across governmental organisations, but also within single organisations, given that flood risk management covers multiple departments.

The second issue is funding. Securing funds for flood risk management measures becomes increasingly difficult as countries reduce budgets. The Floods Directive neither provides a budget for funding nor recommends how to arrange funding for the implementation of measures. In the Room for the River programme funds were secured at the national level for the full programme. The budget was then spent on local projects by regional and local governments. External accountants closely monitor spending.

The third issue is cross-sectoral integration and policy coherence. Agriculture, industry and urban areas are in competition with space reservations for flood-retention areas along the River Rhine. Room for the River projects realise measures that integrate interests of flood risk management, agriculture, industry, nature and urban expansion. The Room for the River case suggests that connections between these sectors should be included in policies from the very start, and that funding should be allocated for measures that integrate various functions. Time should be devoted to exploring integrated options at the local scale, which will enable insights to be gained on the ambitions of the various actors from different sectors and governments (local and regional).

The fourth issue is whether the outcomes of the Floods Directive are reached. The directive is ambitious, in that it aims to change policies from flood control to flood risk management. However, Member States may be wary of sanctions if they do not reach goals that are too ambitious. Instead, regions may opt for 'form' instead of 'content' and merely present plans that do not differ much from current flood policy. For instance, it has been reported that the German Federal States of Hesse and Saxony adapted the tasks of the Floods Directive to their existing routines in a 'pro-forma' implementation process (Heintz et al., 2012). These routines fitted the flood security approach that is characterised by top-down sectoral planning by the water authority.

from ecosystem services, are not always available. The same can be said about Green Infrastructures, where the need for better data is identified (EC, 2013d) to promote green infrastructure solutions in spatial planning and flood-protection infrastructure decision-making processes.

The remaining data gaps must not divert attention from the fact that more and more data are available. Although not generated or assessed specifically for nature-based flood-protection measures, they are very useful, especially at project level. As with measures to adapt to climate change, most of the flood-protection measures based on working with natural processes or NWRMs are low-regret measures. The missing information must not, therefore, prevent projects from being implemented. Better fit-for-purpose information in the future can be expected from the reporting under the Floods Directive, as can further integration of management plans on water and nature and beyond (including sectors like spatial planning, agriculture, tourism, etc.). Nevertheless, to achieve high effectiveness and efficiency from natural water-retention measures, which are beneficial for flood risk management, water management and nature conservation, an assessment based on all information available on catchment or RBD scale remains necessary.

Box 4.5 Recommendations from the implementation of the Floods Directive in the Guadiana basin — a water governance perspective

Various aspects of water governance are well organised in the Guadiana river basin. Roles and responsibilities for policymaking are well defined and water is managed both at the basin and the local scale. Many data are available and are used to inform decisions regarding dam regulation and water allocation. In relation to implementing the Floods Directive, the Spanish have developed a well-conceived plan. It is clear on the roles and responsibilities of various water authorities and states that coordinated participation of all institutional authorities is fundamental in controlling floods. It is coherent with existing policies and proposes measures that are approved by the responsible authorities.

However, there are also several issues that require attention to implement the Floods Directive. The first issue is cross-sectoral coordination. Coordination with other sectors is difficult. Other sectors such as agriculture, industry and spatial planning are much more powerful than water and the environment. They also have more funds. As a result, many activities (e.g. expansion of urban and industrial areas, planting of olive trees) take place in flood-prone areas. This complicates the process of space reservations for flood risk management.

The second issue is capacity. Although a proper FRMP may have been developed, the capacity to implement and enforce it is limited. This is already the case with existing water policies. Owing to the economic crisis, there is very limited budget for water projects. The implementation of measures of the FRMP will improve only with the availability of new financial resources.

The third issue is that of trade-offs across users and generations. Owing to the economic crisis, the main focus is on economic development and there is no attention given to trade-offs between environmental protection and economic development. The next-generation aspect is also not reflected in the implementation of water programmes and projects.

The fourth issue is that of innovative governance. The river basin organisations (Confederaciones) are quite conservative and do not want much to change. Therefore, the implementation of novel measures for flood risk management remains a challenge, because the Confederaciones are the governmental water experts and are responsible for river basin management.

4.4.2 Knowledge and methodology

It remains difficult to quantify, let alone monetarise, all the costs and benefits related to NWRMs, including the opportunity costs such as lost yields, required resources, time to implementation or maintenance costs. This constitutes a barrier for financing and thus implementation (EC, 2015g, 2015i).

As the idea of NWRMs and Green Infrastructures as an essential contribution to sustainable flood risk management becomes increasingly popular, there is still a way to go before such measures are selected as the primary choice for implementation. This is related to the uncertainty of costs and benefits over a longer time period, but also because of uncertainty over maximising the benefits for all economic sectors. A single goals solution has fewer of these uncertainties, but at the same time delivers almost the same potential for ecosystem services and other co-benefits.

A recurring difficulty with interventions in floodplains is the gap between the scientific evidence available and the information needed by decision-makers (Schindler et al., 2013). This includes spatial aspects such as scale (minimum areal requirements), spatial composition and spatial configuration, and temporal aspects such as the minimum time requirements for the generation of particular ecosystem services (Bastian et al., 2012). Difficulties for the implementation of green infrastructure are of a technical (e.g. strength of green infrastructure for flood-protection; hydrological effectiveness of NWRMs, in the short- and long-term) economic and financial (e.g. underpinning of cost-effectiveness and cost-efficiency of measures) and governance (e.g. practical guidelines for implementation) nature.

The lack of reported data on environmental flood impacts may be partly attributed to knowledge gaps in the underlying mechanisms, little experience with flooding of these potentially hazardous objects and difficulties in transferring impacts previously experienced in other floodplains. The guidance documents for reporting under the Floods Directive (EC, 2013a) require an update and clarifications so that replies are more comparable throughout Europe, restress the link with the WFD and make the link to nature policies more obvious.

The impact of socio-economic developments on future flood losses is large. The question is if these developments will be adequately accounted for in the FRMPs.

Although the Sendai declaration on DRR (UN, 2015) talks about improving (environmental) resilience, the focus is on damage and impact reduction of extreme events. Both DRR and flood risk management increasingly look at the whole risk management cycle (see Section 4.1), but where a sustainable flood risk management incorporates co-benefits and the maintenance or elaboration of ecosystems services, this topic is largely absent in the DRR community.

4.4.3 Policies

As stated in the Water Blueprint (EC, 2012d), there remains a need for better implementation of water policies and mainstreaming the water policy objectives into other policies. In a report for the European Parliament it is stated that, in particular with regard to floodplain restoration, the implementation of measures is hindered by a lack of effective tools to design the most cost-efficient measures (Zandstra, 2015). The delayed floodplain restoration across Europe leads to a cost that can be avoided by better implementation of legislation of over EUR 15 billion per year (Zandstra, 2015).

Where water-quality and pollution issues are dealt with in many European policies (e.g. the WFD, but also the Urban Waste Water Treatment Directive, the Drinking Water Directive, the Bathing Water Directive, Integrated Pollution Prevention and Control or the SEVESO Directive), the quantitative management of water in general requires an unanimous decision of the European Council according to the EU treaty (EU, 2012a). The revised CAP includes water-use measures, but the decision to add the WFD to the list of issues for cross-compliance was postponed.

Floodplains are under pressure from both existing and developing activities like urban settlement, infrastructure works or agricultural developments. Spatial planning instruments linking flood risk management to agricultural practices and urban development are lacking or are not enforced. The lack of coherence between sector-specific and water policies is hindering an effective achievement of water policy goals an integrated management of floodplain areas where ecosystem services are maximised.

There is not only a role for EU policies, in domains such as agriculture, energy or navigation, to better coordinate with water policies. A (potential) role can also be seen for financial instruments such as Cohesion Funds when implementing measures relevant for flood risk management and with consequences for the spatial configuration and connectivity of the floodplain. Many planning processes are not steered from an EU-level, but are national or local regulations and policies. The coordination during the implementation of measures can be framed only on a European level (e.g. by imposing stakeholder involvement or cross-compliance) but it has to be implemented on a catchment level.

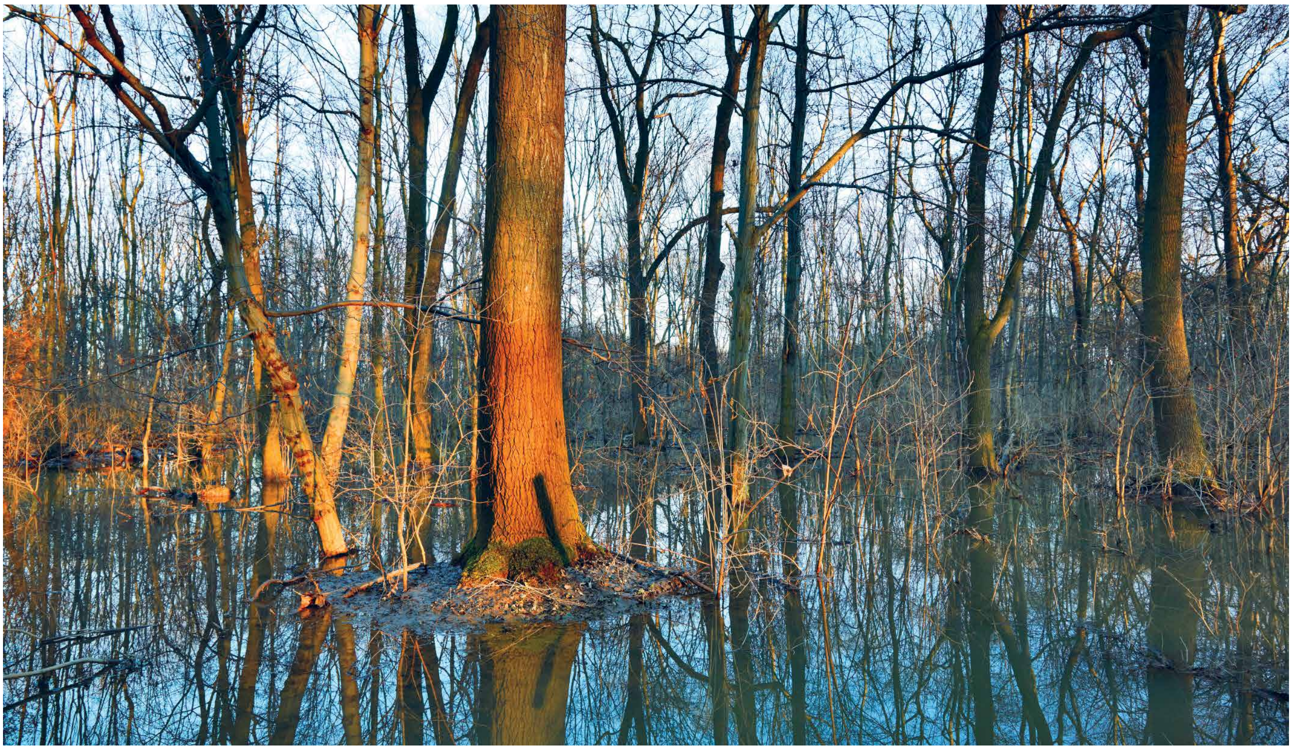


Photo: © André Künzelmann/UFZ

5 Conclusions

'More than any other environmental hazard, floods bring benefits as well as losses' (Smith, 1996).

Floods serve as ecological 'refuelling' or, in the case of extreme floods, even 'reset' buttons (because of the drastic way they alter the landscape). Along with the floodwater and the nutrients it contains, considerable volumes of sediment are moved during flood events; this sediment is eroded from soils on the banks, sorted and transported from the river bed and deposited in floodplains and other areas where the flow velocity is low. These sedimentation processes serve to create and rejuvenate habitats.

Where such flooding is beneficial for the environment, hard/grey flood-protection measures to safeguard industries, infrastructure, settlements and agricultural land often have a negative impact on the environment. In this regard, the Floods Directive differs from the WFD and the Birds and Habitats Directives, where measures have a primary focus on improving the environment; some flood-protection measures have a negative impact on the quality and amount of ecosystem services provided. NWRMs and other nature-based solutions must bring the necessary flood-protection and maintain, restore and improve the ecosystem services delivered by the river and floodplains. However, this will not be possible everywhere and in the localities of cities, power plants, infrastructure and industries hard flood defences will remain necessary for the protection of communities. There is no binary switch between grey and green infrastructure, so even when flood defences protecting against the extremes are seen as a societal necessity, the idea of 'greening the grey' can be adopted to maintain protection with minimal loss of habitat and ecosystem services.

5.1 Floodplains in Europe

Large parts (up to 80 or even 90 %) of the previously intermittently inundated land adjacent to rivers are now disconnected from the river bed or river channel and do not function as active floodplains any longer. Main pressures are economic developments, the regulation of water levels, and loss of connectivity as a result of flood-protection measures.

Land use changes from natural (in central and southern Europe mainly forested) vegetation into agriculture, housing development and industries turn irregular but rather frequent inundations into undesired phenomena because of the economic damage caused. When at the same time the water level is regulated for navigation or hydropower and areas are protected by hard flood-protection measures, the remaining active floodplains are inundated with higher water levels. Nevertheless, remaining floodplains are biodiversity hot spots and they have a key role in sustainable flood risk management, as these are the locations in which NWRMs can be implemented most efficiently and effectively.

5.1.1 Data on floods and floodplains

At first glance, many data on floods and flooding are available throughout Europe, especially on flood hazards. Water levels, discharges, flooded areas are better documented and more easily comparable than the impacts of flooding. The catchment approach has proven useful and will continue to do so. But, as knowledge increases, it is time to take the next step by addressing processes that operate at supra-catchment scales. The most obvious example is climate change. Furthermore, a hydrological analysis of interdependence and correlation of floods in adjacent groups of river basins will support the incorporation of the EU dimension in the estimates and impacts of floods (Merz et al., 2014).

Quantitative information on the impacts of flooding, whether it be fatalities, affected people or (direct) economic damage, is much more difficult to come by on a European scale, as is also the case for impacts on cultural heritage or the environment, where the reporting for the Preliminary Flood Risk Assessments (EU, 2007, Art. 4) showed large gaps across Europe. Further development of the database on past floods, filling gaps and enhancing homogeneity of data by additional guidance on definitions and reporting, will promote its use and increase the usability of the data.

Data can also be generated by computer modelling. Modelling exercises for Europe (Ciscar et al., 2014; Dankers and Feyen, 2008; Rojas et al., 2013) have the advantage of a more homogeneous methodology for use across Europe to increase the comparability of results with natural map inventories. However, a lack of information on remaining and former floodplains, actual flood-protection standards and on the actual technical state of flood-protection infrastructure remains. This level of detail is needed when monitoring and evaluating the status, impact and effectiveness of adaptation efforts (EC, 2013c). Further research into the underlying mechanisms of flooding (e.g. advective versus convective precipitation, snowmelt versus rain) to improve future projections of flood frequencies, timing and depths and thus to help in estimating the effects of flooding on environmental quality, is recommended (Merz et al., 2014). Comparing this information with information on damages and impacts from floods contributes to our knowledge on adaptation and the effectiveness of NWRMs. Although the European-level data aim to provide an overview, based on more or less homogeneous data, this hot-spot analysis is not intended to compete with detailed mapping on a national level, which is needed for detailed catchment scale assessments and the implementation of measures.

The reporting by EU Member States on past floods, as well as the voluntary exercise organised by the EEA ([22]) has resulted in a valuable database at EU level and detailed information at Member State and basin level, which is available to the public ([23]). There is a learning process related to the implementation of the Floods Directive and some elements in the reporting need further clarification in the next reporting cycle, but there is definitely concerted action, and more consistent and detailed outcomes can be expected in future. The next round of reporting will benefit from additional guidelines to further harmonise approaches across the EU. Examples are the non-uniformity in the criteria by which to declare flood events 'significant', or the use of the term 'not applicable', which is sometimes used as 'was checked and was not observed' and in other cases in the sense of 'we do not know because there are no data available' (ETC/ICM, 2013). Based on the draft Flood Risk Management Plans (WRc, 2015), a preliminary conclusion is that international coordination also requires additional efforts.

5.2 Coordination of flood risk management with adjacent policy fields

Many efforts have already been devoted to the coordination of different policy instruments at the European, national and local levels within the water area and with other policy fields. Nevertheless, there is room for further improvement, mainly through better implementation (EC, 2012d). A common definition of goals and objectives from the initiation of projects onwards and with the active involvement of stakeholders (EEA, 2014e) makes the potential synergies between activities competing for and on the same area visible and creates opportunities for innovative financing and a governance model that combines socio-economic with environmental goals.

The links between the Floods Directive, the WFD, the Birds and Habitats Directives and the CAP take place (among others) through measures that modify land use (e.g. by afforestation or by frequently storing excess precipitation). Improved hydrological modelling at catchment scale could reduce the uncertainty about the effectiveness of separate small-scale measures. Subsequently, linking many small-scale measures together to make a real impact on flood risk management requires long-term and deliberate spatial planning.

Case studies in the United Kingdom (Pettifer and Kay, 2012) support the 'intermediate disturbance hypothesis': sites that are frequently and never flooded are less diverse in terms of biodiversity than those that are sometimes disturbed. This calls for approaches that allow intermediate levels of flooding. Changes in land use are often needed for the implementation of these measures. Therefore, spatial planning and stakeholder involvement are of vital importance when implementing a natural flood defence scheme (Moss and Monstadt, 2008).

However, spatial planning is not much subject to EU regulation at present, except for the SEA Directive to a certain extent (EU, 2001), and at sea under the Maritime Spatial Planning Framework Directive (EU, 2014b). However, without spatial planning and effective enforcement, many types of measures will be excluded as a result of socio-economic developments, because the necessary room will simply be occupied by competing uses.

A fully integrated approach between policies considered in this report would require a nexus approach. Elements to be implemented in the short term could be the adoption of a harmonised set of scenarios for climate change and socio-economic development, procedures for using them, and early identification of the effects of planned land use

([22]) See http://forum.eionet.europa.eu/nrc-eionet-freshwater/library/floods/country-review-european-floods-impact-database-2015 for details, accessed 17 November 2015.
([23]) See http://www.eea.europa.eu/data-and-maps/data/european-past-floods, accessed 17 November 2015.

change on hydrology and flood risk management. This identification of effects could be implemented by adding a 'hydrological paragraph' to the SEA and EIA Directives (EU, 2001, 2012b).

5.2.1 Links between topics and policies

There are strong links between the Floods Directive and the WFD, both in procedures and in the programmes of measures. However, further improvements in integration are possible at different levels. At the level of measure implementation, integration is realised due to stakeholder participation, but at national and EU levels, the directives (and their related budgeting and reporting rules) are separated, despite efforts to bridge the gaps (EC, 2014d). The links between the Floods Directive and the Birds and Habitats Directives are to be found in a limited number of procedural arrangements and in field measures that contribute to water-retention while protecting environmental values. The effectiveness of these measures is known in theory but may differ depending on field conditions and lack of monitoring. Many projects on floodplain restoration (e.g. in the LIFE programme) are linked to Natura 2000 sites and make the link between flooding and nature protection in terms of management and measures. The scale of the measures as compared with the scale of the catchment or floodplain is an important factor.

The links between the Floods Directive and CAP are in most cases secondary compared with the links between the Floods Directive, the WFD and the Birds and Habitats Directives. NWRMs offer an opportunity to support water, nature and agriculture policies. The assessment of the effectiveness of these measures for flood risk management requires dedicated hydrological studies. There is no 'one size fits all' solution. Depending on dam construction, and without any concession to safety, a recent development in the hydropower sector is the recognition of the role that dams can have in flood risk management. This offers opportunities for an integrated approach to changes in reservoir management.

5.2.2 Working with natural processes

The implementation of measures is where of all the above comes together. NWRMs are promoted as a nature-based approach. They will be particularly beneficial for smaller flood events. As these happen more regularly, they contribute significantly to the reduction of flood risk (EEA, 2012d; Francés et al., 2008; Pichler et al., 2009). In addition, their capacity to maintain and improve a multitude of ecosystem services should be taken into account when making a societal–environmental cost–benefit analysis, as should their role in climate change adaptation (and mitigation as carbon dioxide and methane sinks).

The uncertainties over their effectiveness, especially during extreme flood events, and the variety of beneficiaries make it hard to make the step from 'in principle agreeing' on NWRMs to their implementation. Examples of good practice and successful projects can be shared, but one of the characteristics is their context dependency, which makes every case different. Stakeholder involvement is, however, key for all of them. In addition, where socio-economic values have to be preserved, the measures must not always be limited to classic hard engineering infrastructures. By 'greening the grey' and making a network of green infrastructures the necessary protection levels are combined with a minimum loss of habitat and a preservation of the remaining ecosystem services to the best extent possible.

A wide variety of structural (where infrastructure is built) and non-structural measures are possible and could be applied when implementing the Floods Directive. Emerging knowledge and technologies should be applied. NWRMs aim to maintain and improve ecosystem services and are part of a wider group of measures that work with natural processes. Measures working with natural processes are not only applied along rivers and in floodplains but also in an urban context (e.g. green roofs or rain gardens) or in coastal areas. Here, an example of a measure working with natural processes but not aiming to increase retention is the 'sand motor' (or sand engine): an innovative method of coast protection and maintenance. Wind, waves and currents will spread the sand naturally along the coast and nature is used to build and maintain natural coastal defences.

Ecosystem-based adaptation and green infrastructure are, in many cases, key in ensuring a cost-effective approach to scenario uncertainty by delaying or avoiding lock-in to classic infrastructure-building water management to provide safety while providing manifold co-benefits for the environment (e.g. the environmental objectives of the WFD) and the different water-using sectors (EEA, 2012c; OECD, 2013). To overcome the bottlenecks in the implementation of measures working with natural processes, the flexibility of the measures needs to be emphasised. These measures, in contrast to most hard defences and engineering works, can be adapted with progressive insights. Even when each case is unique and other pressures and key stakeholders are involved, there are many lessons to be learned from projects that have already been implemented. Therefore, additional guidelines and examples of successes and failures are recommended.

5.3 Guiding principles for next steps in flood risk management

Notwithstanding the different contexts in different countries, the discussion on sustainable flood risk management seems, judging from the evidence presented in this report, to converge in the ambition to apply the following principles underlying the choice of measures.

5.3.1 An inclusive approach to flood risk management

A strategic flood risk management approach that supports sustainability is about more than maintaining the integrity of flood control structures now and over long-term time horizons (Sayers et al., 2015). It includes maintaining, restoring and strengthening the long-term health of all associated ecosystems, societies and economies by promoting key principles (Sayers et al., 2015), namely efficiency and fairness, resilience and adaptive capacity, and safeguarding ecosystem services. There can be trade-offs between safeguarding ecosystem services and safeguarding nature, so that synergies between managing flood risk, promoting ecosystem services and safeguarding nature can be very complex and require some form of spatial prioritisation or the prioritisation of which services to promote.

The synergies between different types of measures, even between different types of infrastructural measures, are often overlooked. Concepts like working with natural processes or NWRMs need to be in the core toolkit of every flood risk manager. They include the use of nature-based solutions to identify infrastructural measures in order to serve multiple purposes and the use of green infrastructure and NWRMs where possible, but combining them with more traditional types of measures where needed.

Regardless of the names used — NWRMs, building with nature, Room for the River, green measures, etc. — working with natural processes is vital to maximise the common goals and objectives of water management, economic development, nature conservation and ecosystem services. These objectives start from an integrated approach at RBD level, which requires improved reporting and implementation practices under the Floods Directive to provide the hot-spot analysis and a European overview. In a following step, the European- and RBD-level overview has to be translated into an overview of national flood risk objectives, which are consistent with those of the WFD, HBDs and the Marine Strategy Framework Directive (EU, 2008).

5.3.2 Economic assessments supporting an inclusive approach

Flood risk management, linking economic, social, environmental and cultural aspects, must be based on socio-environmental cost–benefit approaches, balancing the needs of the environment and the sustainability of ecosystem services with the needs of a multitude of sectors, including safety aspects. This calls for planners to go beyond the economic benefits and include environmental and societal benefits in the assessment of (programmes of) measures (EU 2007, Art. 7 §3). Planners should use the framework of ecosystem services to identify societal costs and benefits of measures (COWI, 2014). The true economic dimension of ecosystem services is often profitable for a broad range of stakeholders and potentially affected people, although it can appear or can actually be negative for others (Grygoruk et al., 2013).

Ecological–economic assessments, such as are currently studied (e.g. (Bateman et al., 2013; Burkhard et al., 2013; Maes et al., 2012; Sullivan, 2012)), are a basic requirement for sustainable development and are necessary for environmental management at country level (Lawton and Rudd, 2013).

Minimising the need for investments will support the adaptive capacity of water managers and will reduce the chances of lock-in situations (OECD, 2015). One option to avoid unnecessary future building liabilities is to apply adaptive management approaches where feasible. Identifying the weakest links may, for instance, demonstrate that before technical measures are designed in detail, efforts should be directed towards improving governance arrangements.

5.3.3 An appropriate role for inherent uncertainties

Flood risk management is surrounded by a multitude of uncertainties. Changes in flood regimes (mean annual discharges, maximum discharges, seasonality) show a mixed pattern across Europe. However, even in those cases in which a trend in flow regime is visible, it is difficult to separate a potential climate change signal from other drivers of change (such as land use or infrastructure). There are indications that the increase in reported flood damage should mainly be attributed to economic development as well as to better reporting, and that an increased flood frequency because of climate change remains uncertain. Nevertheless, climate change deserves priority, because the lead-time for the adaptation of measures is often very long. Scenarios and foresight studies are recommended as tools.

Sustainable solutions look beyond the protection of flood risk management measures and link it to the overlapping areas of vulnerability, environmental quality and the delivery of ecosystem services. Driving forces and pressures, like socio-economic and political developments on all scales (from local to European and global), can be estimated with only a certain level of detail. This has implications for land use, protection of floodplains, or the availability of funding.

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