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D9.2 Case Study Report

Case Study 3: Danube River Basin – harmonising inland, coastal and marine ecosystem management to achieve aquatic biodiversity targets

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List of Abbreviations

ARIES	Artificial Intelligence for Ecosystem Services
BN	Bayesian Network
CEN	European Committee for Standardization
CS	Case Study
D	Driver
DPSIR	Drivers, Pressures, State, Impact, Response model
DFRMP	Danube Flood Risk Management Plan
DRBMP	Danube River Basin Management Plan
EBM	Ecosystem-Based Management
EEA	European Environmental Agency
ESS	Ecosystem Services
EUSDR	EU Strategy of the Danube Region
FD	EU Flood Risk Directive
FW	Freshwater
HBD	EU Habitats Directive and Birds Directive
ICPDR	International Commission for the Protection of the Danube River
NWRM	Natural Water Retention Measures
P	Pressure
S	State
TEN-T	Trans-European Transport Network
WFD	EU Water Framework Directive

About AQUACROSS

Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies (AQUACROSS) aims to support EU efforts to protect aquatic biodiversity and ensure the provision of aquatic ecosystem services. Funded by Europe's Horizon 2020 research programme, AQUACROSS seeks to advance knowledge and application of ecosystem-based management (EBM) for aquatic ecosystems to support the timely achievement of the EU 2020 Biodiversity Strategy targets.

Aquatic ecosystems are rich in biodiversity and home to a diverse array of species and habitats, providing numerous economic and societal benefits to Europe. Many of these valuable ecosystems are at risk of being irreversibly damaged by human activities and pressures, including pollution, contamination, invasive species, overfishing and climate change. These pressures threaten the sustainability of these ecosystems, their provision of ecosystem services and ultimately human well-being.

AQUACROSS responds to pressing societal and economic needs, tackling policy challenges from an integrated perspective and adding value to the use of available knowledge. Through advancing science and knowledge; connecting science, policy and business; and supporting the achievement of EU and international biodiversity targets, AQUACROSS aims to improve ecosystem-based management of aquatic ecosystems across Europe.

The project consortium is made up of sixteen partners from across Europe and led by Ecologic Institute in Berlin, Germany.

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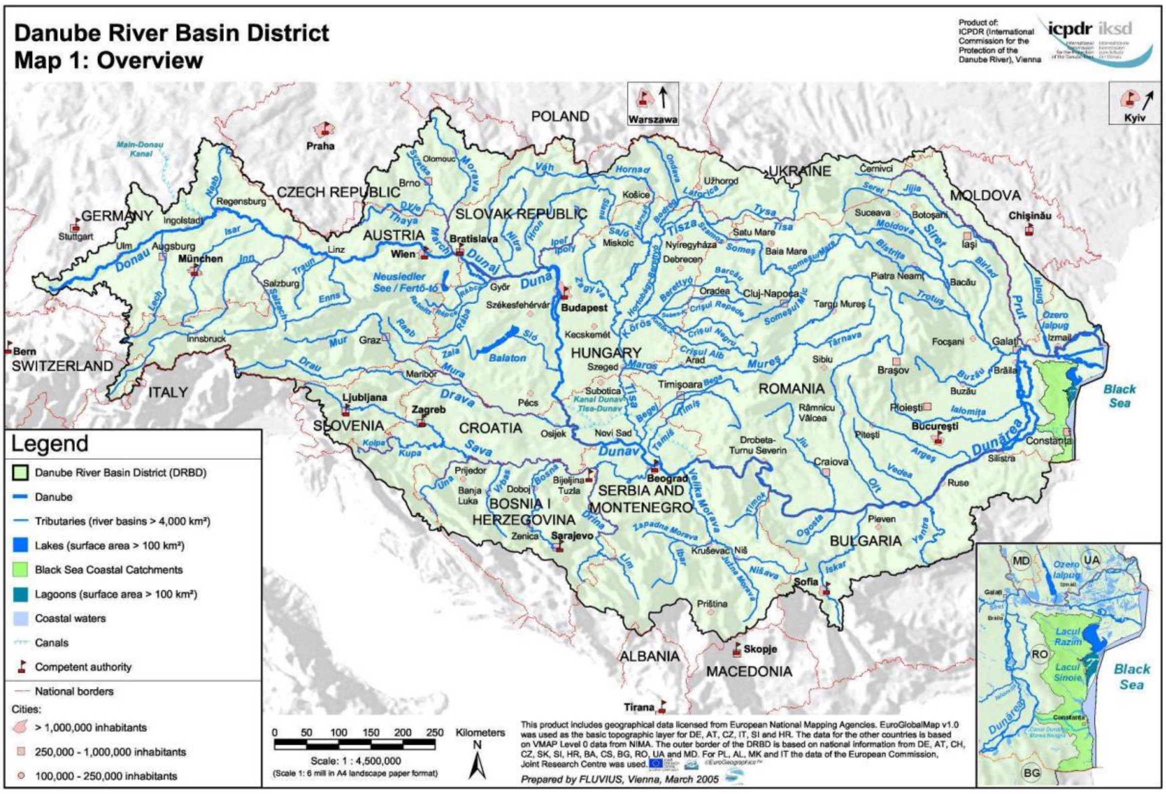
1 Introduction and background

The Danube River Basin is the most international river basin in the world shared by more than 80 million people from 19 countries (Figure 1). 14 countries (having territories of more than 2000 km² within the Danube Basin) are contracting parties of the International Commission for the Protection of the Danube River (ICPDR), which coordinates the conservation, improvement and rational use of Danube waters (ICPDR, 1994). The Danube connects with 27 large and over 300 small tributaries on its wayfrom the Black Forest to the Black Sea, with a catchment size of approx. 800,000km². Accordingly, a huge variety of human activities and related pressures



affect this area.

Figure 1: The Danube River Basin (ICPDR, 2016a).

Hydro-morphological alterations, such as river fragmentation or disconnection of wetlands, are seen as one of the most relevant threats to riverine ecosystems and their biodiversity in general (e.g. Vörösmarty et al. 2010; Schindler et al. 2016) and are specifically relevant in the area of the Danube catchment (e.g. Hein et al., 2016, ICPDR, 2016a). The alteration of natural hydro-morphological conditions can have negative effects on aquatic organisms, which might result in failing the EU Water Framework Directive (2000/60/EC; WFD) environmental objectives of reaching "good ecological status" or "good ecological potential" for all EU surface waters. The most relevant human activities identified in a risk analysis were hydropower, navigation, flood protection and agriculture (ICPDR, 2016a).

Disconnection of floodplains and wetlands represents one significant hydro-morphological alteration in the DanubeRiver Basin (ICPDR, 2016a). The extent of floodplains in the DanubeRiver Basin has been reduced by 68% during the last 150 years (Hein et al. 2016).

Multiple human activities, including the construction of hydropower plants, expansion of agricultural use, and large-scale river regulation measures designed to improve navigation and flood protection, have resulted in this ongoing loss of habitat and biodiversity (Hein et al. 2016, ICPDR, 2016a). Additionally, forestry, urbanisation and aquaculture are seen as important drivers of floodplain reduction for different regions along the Danube (Hein et al. 2016). Constricting lateral connections to the river's main channel transforms a floodplain into a sediment sink, and consequently initiates aggradation processes (e.g. Schiemer, Baumgartner & Tockner 1999; Hohensinner et al. 2008, Reckendorfer et al. 2013). This leads to a further disconnection of the floodplain system and a loss of (aquatic) floodplain habitat and biodiversity. Nevertheless, river-floodplain systems still represent hotspots of biodiversity conservation and provide multiple ecosystem services (Hein et al. 2016, Schindler et al 2016). The alteration of hydro-morphological conditions has also been identified to be the main pressure for floodplain biodiversity at an European scale (Schindler et al. 2016). The effects of morphological changes and degradations in combination with hydrological alterations along the Danube (Habersack et al. 2016) as well as it's impact on biodiversity (Funk et al. 2019) are not sufficiently understood. This case study aims to address this lack of understanding, and therefore, focuses on multiple hydro-morphological pressures at the catchment scale and their effects on biodiversity and ecosystem service provision along the Danube and how management can be improved.

In this case study, we apply the AQUACROSS Assessment Framework (Gómez et al. 2017), to identify how current management of river-floodplain systems along the Danube can be supported. Therefore, it links available multi-disciplinary information in an innovative way and creates a basis for a more integrated management and restoration planning of river-floodplain systems in line with the principles of ecosystem-based management (EBM). In particular, throughout, we apply the EBM principle of focusing on multiple ecosystem services, across multiple policy targets and aiming to maximise their joint value. The approach also aims to foster transboundary coordination and cooperation as it is considering the whole navigable main stem of the River Danube (ecosystem scale) independent from jurisdictional, administrative and political scales (e.g. country scale).

A policy analysis (chapter 2) supports the identification of challenges in implementation of existing policies and the identification of appropriate EBM responses. The AQUACROSS linkage framework, the operational tool of the AQUACROSS assessment framework (Borgwardt et al. 2019, Teixeira et al. in revision) is used to explore linkages between pressures, ecosystem components, and ecosystem services at the basin scale, and is supplemented with detailed analysis of specific sections of the identified linkages in the system, and impact of hydro-morphological alteration of the river-floodplain systems of the navigable Danube (chapter 3). A prioritisation of the river-floodplain systems for restoration and conservation (chapter 4) is conducted using a novel integrative modelling approach. Finally prioritised sites are evaluated against a baseline scenario, restoration sites proposed under WFD at member state level according to national criteria, considering multiple targets related to biodiversity, ecosystem services and socio-economic benefits (chapter 5).

Box 1: **Further important case study topics**

Hydropower in the catchment

In the Danube catchment there are a large number of hydrological alterations, such as water abstraction, impoundments and hydropeaking (ICPDR, 2013a). The construction of hydropower dams represents one of the most severe pressures affecting the integrity of river ecosystems, as it involves the modification of riverine habitats, the transformation of a river section into reservoir stretches, modifications of the hydrological regime, of water temperature, turbidity, sediment load, and the interruption of river continuity, which may cause large-scale effects for the whole river system (Parasiewicz et al., 1998; Vörösmarty et al., 2010; Gracey & Verones, 2016). Thus, the construction of hydropower dams represents a clear threat to regional aquatic biodiversity and to several ecosystem services provided by river corridors to humans (Dugan et al., 2010; Wang et al., 2010).

The impact of hydropower on the river hydrology and biodiversity is analysed in detail in Annex1 and Costea et al. 2018.

Cyanobacteria blooms in the Danube Delta

The Danube Delta is faced by serious cyanobacteria bloom risks due to eutrophication and climate change. At the same time, it is vulnerable to ecological decline, which also involves challenging issues of biodiversity conservation, restructuration of the wetlands and improving human well-being. Due to the hydro-morphological structure of the Delta, the release of sedimentary phosphorus, and cyanobacteria's ability to use nitrogen from the atmosphere as a nutrient source, cyanobacteria have been spread to all available niches (Török et al., 2017). The occurrence of high cyanobacteria biomass in phytoplankton communities coupled with low autotrophy to herbivores energy-transfer efficiency has an impact on water quality, which leads to changes both at the bottom and the top of the food chains (Monchamp et. al., 2017). Even more than that, cyanobacteria have a potential toxic effect, which may increase the risk of toxin related health problems in resting or feeding areas of the wildlife protected species. Consequently, aggregation of cyanobacteria, concentrated by wind activity, could have high impact on aquatic biodiversity if no action to mitigate their effect is taken.

Therefore, we analyse perceptions of stakeholders on algal blooms in aquatic systems in the Danube Delta in order to identify potential adaptation and mitigation strategies for the future (Annex 2 and Costea et al. 2018).

2 Establishing objectives

2.1. Identifying policy objectives

The Danube river basin is shared between 19 countries, of which 11 are EU member states and four are candidate countries. Out of the total area of about 800,000 km², in total 90% lie either within EU territory (79%) or in EU candidate countries (11%). Referring to the scope of the case study on catchment scale, priority has been given to policy documents, which target the Danube river basin district as a whole (or at least all Danube countries which are part of the EU). This information has been complemented by EU-level instruments, in cases where no similar instrument could be identified at Danube catchment scale. The chapter provides an overview of relevant policy instruments, their multiple objectives and targets having a link to hydro-morphological restoration.

The **EU Biodiversity Strategy to 2020** has six overarching objectives, two of which are particularly relevant in the context of the AQUACROSS Danube case study, given its focus on hydro-morphological alteration and restoration. The other targets apply as well for the Danube river basin as a whole. The full implementation of the Habitats and Birds Directives constitutes the first target of the EU Biodiversity Strategy. Also, the EU Biodiversity Strategy establishes a 15% restoration goal on degraded ecosystems under Target 2 linking strongly to EU Water Framework Directive.

The second **Danube river basin management plan** (ICPDR, 2016a, DRBMP), which has been elaborated under the **EU Water Framework Directive** (2000/60/EC; WFD) and was published in 2015, is of outstanding importance as an environmental policy instrument at the whole Danube level. It provides a basin-wide overview of the efforts made to reach good ecological status or good ecological potential of all water bodies - an objective set by the WFD, which is so far widely not reached also owing also to hydro-morphological alteration. The DRBMP specifies that regarding river morphology, 73% of the river water bodies are under pressure through morphological alterations. Reconnection and restoration of floodplains/wetlands is defined as a measure of basin wide importance in the DRBMP. The implementation of the WFD is in particular contributing to target 2 of the Biodiversity Strategy to 2020 (restoration of degraded ecosystems), but also positively impacts target 1, the full implementation of the Nature Directives.

Additionally, flood risk management may significantly influence hydro-morphological characteristics of water bodies, which gives particular importance to **the EU Flood Risk Directive** (2007/60/EC) and the **Danube Flood Risk Management Plan** (DFRMP, published in 2015) elaborated in that framework. The DFRMP mentions both structural measures (dikes, dams, flood protection walls, etc.) and natural water retention measures (NWRM) as measures for reducing existing risks but indicates a clear preference for NWRM. In practice, the implementation of NWRM often enables creating synergies with the objectives of other environmental policies, especially the WFD. The implementation of NWRM directly contributes to target 2 of the EU Biodiversity Strategy to 2020, which includes the restoration and promotion of the use of green infrastructure.

With regard to the nature directives themselves - the **Birds Directive** (2009/147/EC) and the **Habitats Directive** (92/43/EEC) (**HBD**)- which aim at reaching favourable conservation status of habitats and species in protected areas and beyond. At European scale, as well as along the Danube, a large proportion of the remaining floodplain area is protected by the Habitats (HD) and Birds Directives (BD) (Schindler et al. 2016). The main goals of nature protection are furthermore underpinned by different initiatives. An example is Sturgeon 2020, a program for the protection and rehabilitation of sturgeon species promoted under the EUSDR. The sturgeon is a flagship species for the Danube, and an excellent indicator for habitat quality and connectivity (Sandu, 2012). Many measures which support sturgeon species will therefore also produce benefits for other migratory fishes (see project MEASURES http://www.interreg-danube.eu/approved-projects/measures).

At the Danube level, the **EU Strategy of the Danube Region** (CEC 2010a, b, EUSDR) is also relevant, as it sets a target for biodiversity and ecosystem restoration at the Danube catchment level in Priority Area 6. Direct links can be made between the targets of this priority area and the targets 1 (Fully implement the Birds and Habitats Directives), 2 (15% restoration goal on degraded ecosystems) and 5 (Combat Invasive Alien Species) of the EU Biodiversity Strategy to 2020. In general, the EUSDR has the ambition to contribute to the integration with other, in particular sectoral policy objectives, such as the improvement of navigation.

Regarding sectoral policies, policies linked to navigation and hydropower are the most relevant ones, given the importance of the two sectors as drivers of hydro-morphological alterations of the Danube.

For hydropower, the **EU Renewable Energy Directive** 2009/28/EC is an important driver for hydropower development. The Directive aims for 20% of total EU energy needs to be supplied from renewable sources by 2020. A proposal for revision of the Directive to aim for the target of 27% renewables by 2030 was published at the end of 2016, but has not yet been adopted. Each member state has been appointed individual national targets to be achieved by a national action plan. Half of the Danube countries are not yet to reach their targets for the EU Renewable Energy Directive and therefore further investments on hydropower can be expected. Perhaps even more influential than the targets themselves are the financial subsidies which have been introduced by many EU member states, for owners of existing hydropower plants, and for investors who construct new hydropower plants (Sikorova & Gallop, 2015). In non-EU member states institutions such as the Western Balkans Investment Framework (WBIF, 2017) and the European Bank for Reconstruction and Development (EBRD, 2011), facilitate investments into hydropower (Bankwatch, 2015).

With regards to navigation, the **Trans-European Transport Network** (EC 2013, TEN-T) represents a policy framework that promotes navigation (and other traffic and information infrastructure) and aims to reach good navigability for important waterways. This includes removing multiple obstacles along the Danube (critical locations) where the main channel does not achieve the targeted depth for navigation. The "Fairway Rehabilitation and Maintenance Master Plan for the Danube and its Navigable Tributaries" (Fairway Danube, 2014), has been developed as part of the EUSDR in 2014, and "highlights national needs and short-term measures in order to ensure the efficient and effective realisation of harmonised waterway infrastructure parameters along the entire Danube and its navigable tributaries" (Fairway Danube, 2017). In the past, the projects PLATINA I and II were also important for the promotion of inland waterway transport. Starting in 2008 and ending in 2015, they were designed as a platform to provide support for the implementation of the "European Action Programme for the promotion of inland waterway transport" (NAIADES).

Our analysis of policy targets revealed that deficits in reaching agreed policy targets are relevant in the Danube region. Especially the DRBMP specifies that regarding river morphology, 73% of the river water bodies are under pressure through morphological alterations. However, especially related to the EU Biodiversity Strategy to 2020 as well as the Birds and Habitats Directives, clear indicators at the Danube level are missing. For those it is – based on the information assessed – not possible to state to which extent targets have been reached. Also, the EUSDR gives no clear quantification of the deficit or progress to the ecological targets either.

Policy synergies and conflicts

Hydro-morphological pressures interact with the management goals of the WFD or Nature Directives (Habitat and Bird Directive, Biodiversity strategy to 2020), resulting in potential synergies and conflicts between the various management goals (Rouillard et al. 2016). Thereby, pressures exerted by human activities often reduce the availability of some other ecosystem services and may also significantly affect the implementation of policy goals. Similarly, the implementation of sectoral policies on hydropower (renewable energy), navigation, and flood protection show significant synergies and antagonisms, too, and the interaction of their implementation significantly influences the actual type and extent of pressures on rivers. An important example for a potential synergistic effect on floodplain management and protection is related to sustainable flood risk management. The EU floods directive (FD) aims at reducing risk of flooding along water courses e.g. including natural water retention measures (NWRM i.e. flood protection in natural ways by dyke relocation, providing more space for the rivers), and thus, floodplains represent a key element of the EU Green Infrastructure Strategy (ICPDR, 2016a). Like-wise navigation projects (related to TEN-T Regulation) might either have a synergistic effect on nature protection goals in already significantly altered river-floodplain sections (if ecological restoration is supported within the project), or an antagonistic effect in intact river-floodplain sections where every intervention may create a conflict with nature protection goals (DANUBEPARKS, 2011). Summing up, the various directives and management targets have synergistic as well as antagonistic effects dependant on the situation as their interactions are complex and not sufficiently understood. In conclusion, considering those multiple objectives related to biodiversity, ecosystem services and socio-economic benefits within one approach could greatly facilitate the implementation of **ecosystem-based management (EBM)**.

2.2. Co-design

Based on the analysis of main EU policies in chapter 2.1, key stakeholder groups and networks directly related to those policies were identified in a first step. The focus of those key stakeholders, their interactions and their input for the case study are summarised in the following sections:

- ***WFD and FD:*** The International Commission for the Protection of the Danube River (***ICPDR)*** coordinates the implementation of Floods Directive (ICPDR 2016b) and Water Framework Directive (ICPDR 2016a). ICPDR is an International Organisation consisting of 14 cooperating states and the European Union. Since its establishment in 1998, the ICPDR has grown into one of the largest and most active international bodies of river basin management expertise in Europe. The ICPDR deals not only with the Danube itself, but also with the whole Danube River Basin, which includes its tributaries and ground water resources. It works to ensure the sustainable and equitable use of waters and freshwater resources in the Danube River Basin. The work of the ICPDR is based on the Danube River Protection Convention, the major legal instrument for cooperation and trans-boundary water management in the Danube River Basin. For many economic activities, the ICPDR has developed guidelines to align them with environmental needs. This includes the guideline on “Sustainable Hydropower Development in the Danube Basin” (ICPDR, 2013b) as well as the “Joint Statement on Inland Navigation and

Environmental Sustainability in the Danube River Basin" (ICPDR, 2007), the "Manual on Good Practices in Sustainable waterway Planning" as well as a strategy for climate adaptation "ICPDR Strategy on Adaptation to Climate Change" (ICPDR, 2013c).

Co-design: In the initial phase of the AQUACROSS project, the link with the ICPDR was developed. The ICPDR support the project and progress updates have been regularly presented in the framework of annual Ordinary Meetings and Standing Working Groups Meetings of the ICPDR since 2015 throughout the whole project. Key policies, drivers, and environmental deficits related to hydro-morphological alteration (see chapter 2.1 and 3) were identified based on the comprehensive data and information compiled by ICPDR (ICPDR, 2015, 2016a, b) and presented during the various meetings. Data on hydro-morphological alterations provided by the ICPDR are further essential indicators in the assessment approach of the case study. In 2017/18 the focus of the case study the objectives of the analysis, the modelling approach and management scenarios were presented in face to face meetings to the ICPDR. In 2018 case study members participated in the 19th ICPDR Hydromorphology Task Group Meeting and 27th ICPDR Monitoring and Assessment Expert Group meeting, where AQUACROSS, the objectives of case study and the assessment approach were introduced and presented. Further interactions in the later project phase and follow up of the project will focus on the potential for take-off of project results.

- **DANUBEPARKS** (http://www.danubeparks.org/) is a network of protected areas (national parks, biosphere reserves, nature parks) in the Danube region, which aims at enhancing nature conservation of Danube river protected areas, including coordination of the management and development of the Natura 2000 network (**HBD**), through information exchange on good practices and the common implementation of measures. Danubeparks is also in cooperation with the ICPDR as an observer.

  Co-design: In 2017 case study members participated in a project workshop of the DANUBEPARKS network, where the objectives, environmental indicators and assessment approach of the case study were presented. Biodiversity indicators and availability of further biodiversity data, relevant policies, management scenarios as well as potential take-off of the results were presented. One conclusion was that detailed homogenous datasets related to biodiversity in floodplains are widely lacking along the Danube.

  TEN-T**: **viadonau provides for a safe and efficient waterway, maintains and improves habitats along the Danube and promotes innovative solutions for environmentally friendly ship traffic. In addition, viadonau is continually installing and modernising systems related to flood protection in Austria (link to **FD**), It coordinates with the waterway authorities from all countries along the Danube during the implementation of international projects e.g. supporting the development of the Rhine-Danube Corridor as part of the trans-European transport network (TEN-T). viadonau has implemented and is further planning a number of projects to improve and preserve the habitats of the Danube based on the legal requirements of the **WFD** and the Natura 2000 directives (**HBD**). These have been achieved partially thanks to the support of the EU's environmental funding program LIFE.

  Co-design: In 2018 a face-to-face meeting with viadonau was organised, where the assessment approach of the case study and prioritisation results were presented and the potential for take-off of the results for the planning of restoration sites was discussed (see chapter 5.4 for more details).

- **EU Renewable Energy Directive: VERBUND** is one of the largest producers of electricity from hydropower in Europe. It is member of the **VGB PowerTech e.V.,** the international technical association for generation and storage of power and heat, which was involved in the development of the guidance document on "Sustainable Hydropower Development in the Danube Basin" (ICPDR, 2013b). VERBUND also invests in environmental projects and ecological measures to safeguard biodiversity based on the legal requirements of the WFD and the Natura 2000 directives (HBD), often supported by the EU's LIFE programme.

  Co-design: Verbund participated in the AQUACROSS workshop (see also chapter 5.2.1).

In the later phase of the project a **case study workshop** "Impact of hydro-morphological alteration and restoration in the light of biodiversity and ecosystem services – exploring synergies for the WFD" was organised on July 5th, 2018 by the AQUACROSS case study team at the 42nd Conference of the International Association for Danube research (IAD) bringing together more than 30 scientists, managers, business representatives and NGO's of the Danube region. Results of the assessment approach for the Danube were presented. Within an interactive session the importance of benefits (ecosystem services) and challenges associated with river-floodplain restoration were discussed and evaluation criteria for the assessment of restoration measures were set (see chapter 5.2.1).

3 Assessing the current state of the social-ecological system

3.1. Linkage framework

Linkage-based frameworks are used to characterise complex human and ecological relationships (Elliott 2002; La Jeunesse *et al.* 2003; Holman *et al.* 2005; Knights *et al* 2013) and were therefore used in a first step to analyse the complex situation of the socio-ecological system of the Danube. The AQUACROSS linkage framework (Pletterbauer et al. 2017, Nogueira et al. 2017, Borgwardt et al. 2019, Teixeira et al. in revision) as the selected operational tool related to the AQUACROSS assessment framework takes a Driver-Pressure-State-Impact-Response (DPSIR) approach (EEA 1999). The framework consists of interconnected matrices linking the social-side of the complex social-ecological system (i.e. drivers and human activities that place pressures on ecosystem components) to the supply-side of the system (i.e. ecosystem biodiversity) supporting ecosystem functioning and delivering ecosystem services, which in turn fuel the social-side of the system.

The definitions of activities and pressures are based on previous classifications from the Habitats Directive (HD), Water Framework Directive (WFD), and Marine Strategy Framework Directive (MSFD) (EC 1992, 2000, 2008), as well as statistical classification of economic activities (EC 2006) and previous typologies (White *et al.* 2013; Smith *et al.* 2016). The state term 'was described in terms of 'ecosystem components' which included habitats (based on definition of the EUNIS habitats (Davies *et al.* 2004) occurring in the case study areas (EUNIS level 2 or level 3)), as well as mobile biota groups (amphibia, birds, fish, adult insects, mammals, and reptiles). Ecosystem services are defined based on CICES (https://cices.eu/).

From these references lists of possible human activities, pressures, ecosystem components, ecosystem functions and services were collated, and matrices were created and filled in, which provided the linkages among those. With one activity causing many pressures, different activities being able to cause the same pressures, and the pressures themselves affecting various ecosystem components, the linkage framework paints a complex but detailed picture of the relationships between human activities and the status of various ecosystem components by exploring impact chains (Knights *et al.* 2013).

The AQUACROSS linkage framework for the Danube case study identified 53 specific activities taking place. Furthermore, 35 different pressures in five different categories (biological, chemical, physical, energy, and exogenous/unmanaged) were identified, as well as 33 ecosystem components (27 habitats and 6 biotic groups). These components were linked to 19 ecosystem services (ESS). Over 23,000 impact chains were identified and categorised.

To investigate the impact chains, their connectance was calculated. Connectance describes the percentage of the number of linkages per category in relation to the total number of linkages (Gardner and Ashby 1970). The higher the value, the better the connectance of the category throughout the linkage framework. While this does display the how well connected an activity, pressure, ecosystem component, or ESS is, it does not express the strength of these relationships, just their existence. Therefore, the linkages where additionally weighted in terms of the extent, frequency, dispersal, severity and persistence of interactions to increase their explanatory power. With the help of these weightings an environmental impact risk score was developed, indicating the potential threat to ecosystem components (Borgwart et al., in revision; Pletterbauer et al. 2017, Nogueira et al. 2017). This process was conducted based on information from literature research and expert judgement, following the categorisation described in Borgwart et al., (in revision).

Looking at the impact risk of pressures on ecosystem components (Figure 2), it is evident that physical change poses the highest threat to freshwater (FW) realms and to fish. Physical pressures are highly linked to activities of environmental management and hydropower endorsing our choice to focus on hydro-morphological alterations in this case study.

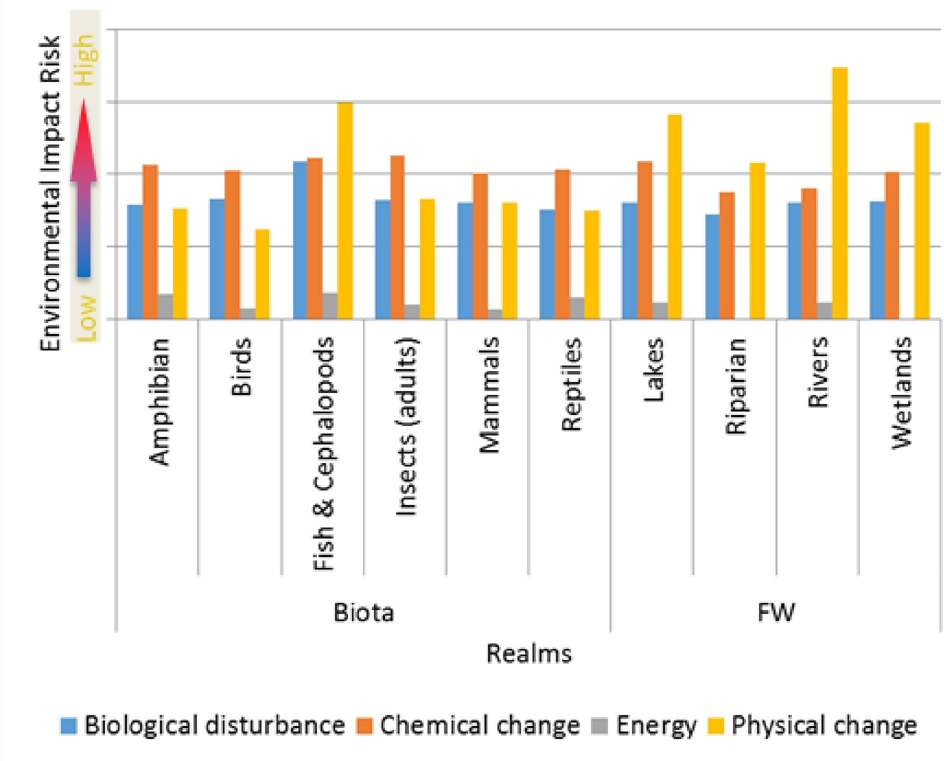


Figure 2: Environmental impact risk of pressure categories on realms (for detailed description of impact risk see Borgwardt et al. 2019).

To characterise the supply side of the socio-ecological system in the Danube River Basin, ecosystem components (representing biodiversity) and their related ESS were linked. The ecosystem components within the Danube catchment have the capacity to supply 19 ESS (regulating and maintenance, provisioning, and cultural services). Floodplains with their riparian forests and wetlands proof to be the highest connected realms and therefore providing a great variety of ecosystem services (see Figure 3).

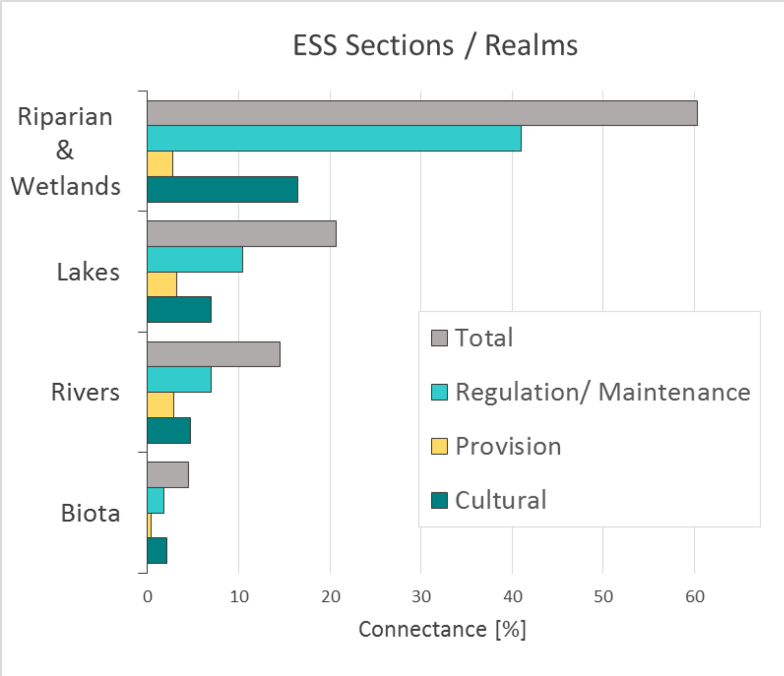


Figure 3: Linkages (connectance in percentage based on impact chains) between ecosystem components of the Danube case study to their ecosystem services. Riparian: riparian/floodplain forests; Wetlands: wetlands and floodplain water bodies; Biota: actively moving biota including fish and insects.

Overall, results from the linkage framework support the focus on hydro-morphological pressures in the Danube case study and the importance of functional intact floodplains and wetlands for human well-being.

3.2. Detailed assessment of current Drivers-Pressures-State-Biodiversity-Ecosystem Functioning-Ecosystem Services

As also supported by the analysis of the linkage framework, hydro-morphological alteration of river-floodplain systems represents an important pressure in the Danube River Basin (ICPDR, 2016a). Therefore, we focus within a quantitative approach specifically on river-floodplain systems along the navigable main stem of the Danube River, where the interactions of several human activities and pressures related to hydro-morphological alteration on biodiversity and ecosystem services are quantified.

Indicators

Following the approach of AQUACROSS for the selection of indicators (Pletterbauer et al. 2017, Nogueira et al. 2017), we focus on existing **indicators** that are currently used in relation to relevant EU policies. These fulfil many of the requirements for good indicators: 1) they have a high political relevance; 2) there is a clear orientation towards environmental targets (e.g. good conservation status for HBD); 3) information on estimations of normative values is available (e.g. European Committee for Standardization, CEN standards); 4) data are widely available; 5) thus the indicators are also cost-effective, 6) information is already provided on the (policy) relevant spatio-temporal scales; and 7) in most cases, there is a high degree of transparency, including a reproducible methodology (e.g. CEN standards).

In a first step, indicators were reviewed that are used across the different relevant policies and which are related to hydro-morphological alterations. Subsequently data availability was checked across open access sources and stakeholders were contacted for available data (see Annex 3 for selected indicators). We used open access data including a continuous hydro-morphological assessment for the navigable Danube River compliant with CEN standards (Schwarz, 2014, ICPDR, 2015). Land cover/Land use (LCLU) data were obtained from the European Riparian Zones dataset developed by the local component of Copernicus Land Monitoring Services (http://land.copernicus.eu/). In addition, data collected on the status of the waterway, critical locations for navigation and navigation class (Fairway, Danube, 2014), as well as information on position and impacted river length for hydropower plants (https://danubis.icpdr.org/) were included. Finally, information on conservation status of widely distributed protected species, including fish and amphibians, collected for HD and BD for approximately 120 sites along the navigable stretch of the river Danube were integrated. For Natura 2000 sites information is provided within a pan-European database of the EEA (www.eea.europa.eu). Therefore, our approach is expected to provide a first statistical proof of multiple relationships of biodiversity and ecosystem services along the navigable stretch of the Danube River and is further serving as a basis for a strategic and more integrated management approach.

Methods

Cause-effect relations for the selected metrics along the Driver-Pressure-State chain were analysed within a quantitative Bayesian Network approach based on bootstrapping following Friedman et al. (1999), an approach which can detect causal relationships based on statistical relationships of quantitative data. We used a score-based structure learning algorithm to analyse the causal structure within the network of interactions between driver, pressure and state variables as our data set is small, as in turn constraint based algorithms are known to require very large datasets for their performance. A bootstrapping approach was used to estimate the importance of the possible links in the network expressed as a probability for certainty of potential links and knots using the approach of Friedman et al. (1999). Finally, we compared our resulting networks to the existing knowledge base related to those species (for more detail see Costea et al. 2018). The importance of drivers for the conservation status of the different species was further analysed using **sensitivity analysis** (Marcot 2012).

Three essential **ecosystem services** were included in the analysis, flood regulation directly linking to the EU Flood Risk Directive, crop pollination, which links directly to the importance of floodplains for agricultural production, and recreation potential as an important service in the mainly urbanised and agricultural landscapes surrounding the Danube. The ARIES (ARrtificial Intelligence for Ecosystem Services) platform was used for assessing those services for the Danube River and its floodplains. ARIES is an open-source technology capable of selecting and running models to quantify and map all aspects of ecosystem service provision, including their biophysical generation, flow and extraction by sinks and beneficiaries (Villa et al. 2014). A detailed description of all ecosystem service models can be found in Martínez-López et al., 2019.

Results

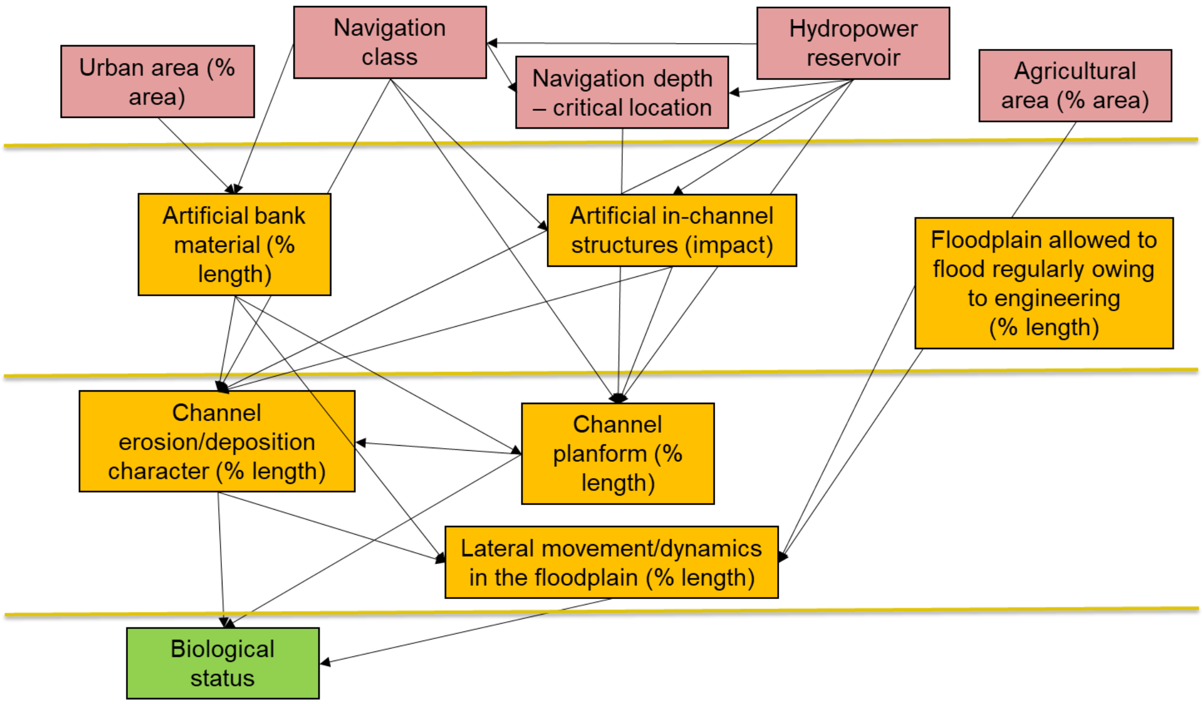


Figure 4: Resulting Bayesian Network of the Driver-Pressure components causal links, calculated via bootstrapping following the approach of Friedman et al. (1999).

The resulting Bayesian Network (Figure 4) shows the multiple **causal relationships** between the different D-P parameters. The results are generally in concordance with scientific knowledge (compare e.g. Graf, 2006, ICPDR, 2016a, Habersack et. al. 2016, Hein et al. 2016, Hein et al. 2018) and consequently, also proof of good representability and sensitivity of the metrics and validity of the network approach. Linkages show that hydropower supports the navigability of the river, as in the deep and relatively wide reservoir sections no obstacles for navigation are present. On the other side, in the reservoir sections of the hydropower plants patterns of erosion and deposition as well as river planform are significantly altered. The resulting network also shows the alteration of the river channel for navigation. In order to improve navigability, engineering structures within the channel were constructed and banks were stabilised by artificial structures consequently also disconnecting adjacent floodplains. Planform and erosion/deposition patterns in the river were significantly altered e.g. due to the creation of artificial secondary channels for navigation. Critical locations for navigation are situated in areas with more natural planform and vice versa; planform must be altered to remove critical locations. We can also show that for urbanisation, intense bank stabilisation measures were conducted in order to limit flooding of the floodplain. Agriculture in the riparian area led to a significant decrease of total as well as connected floodplain area (compare Hein et al. 2016, ICPDR, 2016a).

In addition, causal links detected for indicators of the HBD (Annex 3) are in concordance with the basic knowledge on species traits and habitat use of the selected protected species, they therefore show representativeness and validity of the network approach. Probability for relationships for the P-S indicators showed that species are most likely impacted by the alteration of planform of the river followed by alteration of erosion/deposition features and floodplain connectivity. Typical floodplain species (e.g. *Gymnocephalus baloni, Triturus dobrogicus*) and stagnotopic (species preferring stagnant water bodies) species (e.g. *Rhodeus amarus, Misgurnus fossilis*) showed stronger relationships to connectivity than rheotopic (species preferring water bodies with lotic conditions e.g. *Gymnocephalus schraetzer, Zingel streber*).

Further results of **sensitivity analysis** (see Annex 3) show that stagnotopic and typical floodplain species are negatively impacted by the intensity of urbanisation and therefore intensity of flood protection measures. For rheotopic species hydropower and navigation have a relatively high impact, as human activities related to those drivers are directly impacting the hydro-morphological conditions in the main stem. This is also reflected in the significant correlation of the fish region index (FRI) with the relative importance of navigation and urbanisation driver across fish species.

Our analysis also showed different **ecological thresholds** (see Annex 3) of stagnotopic and rheotopic species along the pressure gradients. Whereas rheotopic species likely fail good conservation status at relatively low levels of alteration, stagnotopic species have a relatively high probability to have a good conservation status even at high levels of alteration. This pattern reflects well the knowledge from restoration literature. River regulation leads to a drastic shift in the composition of habitat types (e.g. Schiemer et al 1999). With increasing disconnection, especially rheotopic elements will decline, while biotic elements characteristic for lentic conditions in floodplains decrease less rapidly. In contrast, for all selected species an excellent conservation status was highly probable only at sites with low intensity of human alteration. There is a clear overall threshold at a relatively low level of alteration already. Therefore, excellent conditions for species most likely occur under near natural conditions.

After testing, in a next step (chapter 4, Funk et al. in revision) D-P-S networks are used as a predictive tool.

4 The baseline and future scenarios

4.1. Identifying gaps between baseline and objectives

Within AQUACROSS a **Baseline scenario** is defined as a shared view of past, current and prospective trends and vulnerabilities in ESS and biodiversity, associated challenges and opportunities, in a case study (Gómez et al. 2017).

In the Danube River Basin Disconnection of floodplains and wetlands represents a significant hydro-morphological alteration. This includes channelisation and reduction of lateral exchange processes and floodplain areas.

In the current state, clear deficits related to EU WFD (Water Framework Directive) and HBD (EU Habitat and Birds Directive) objectives are obvious. Across the whole navigable stretch of the Danube the good ecological status or potential according to the WFD is not met (Figure 5). In the upper Danube in most of the sites protected under the HBD species do not reach good conservation status, whereas in the lower Danube good conservation status is widely reached (Figure 5). This is in good concordance with the level of hydro-morphological alteration, as already comprehensively analysed and discussed in chapter 3 of this report.

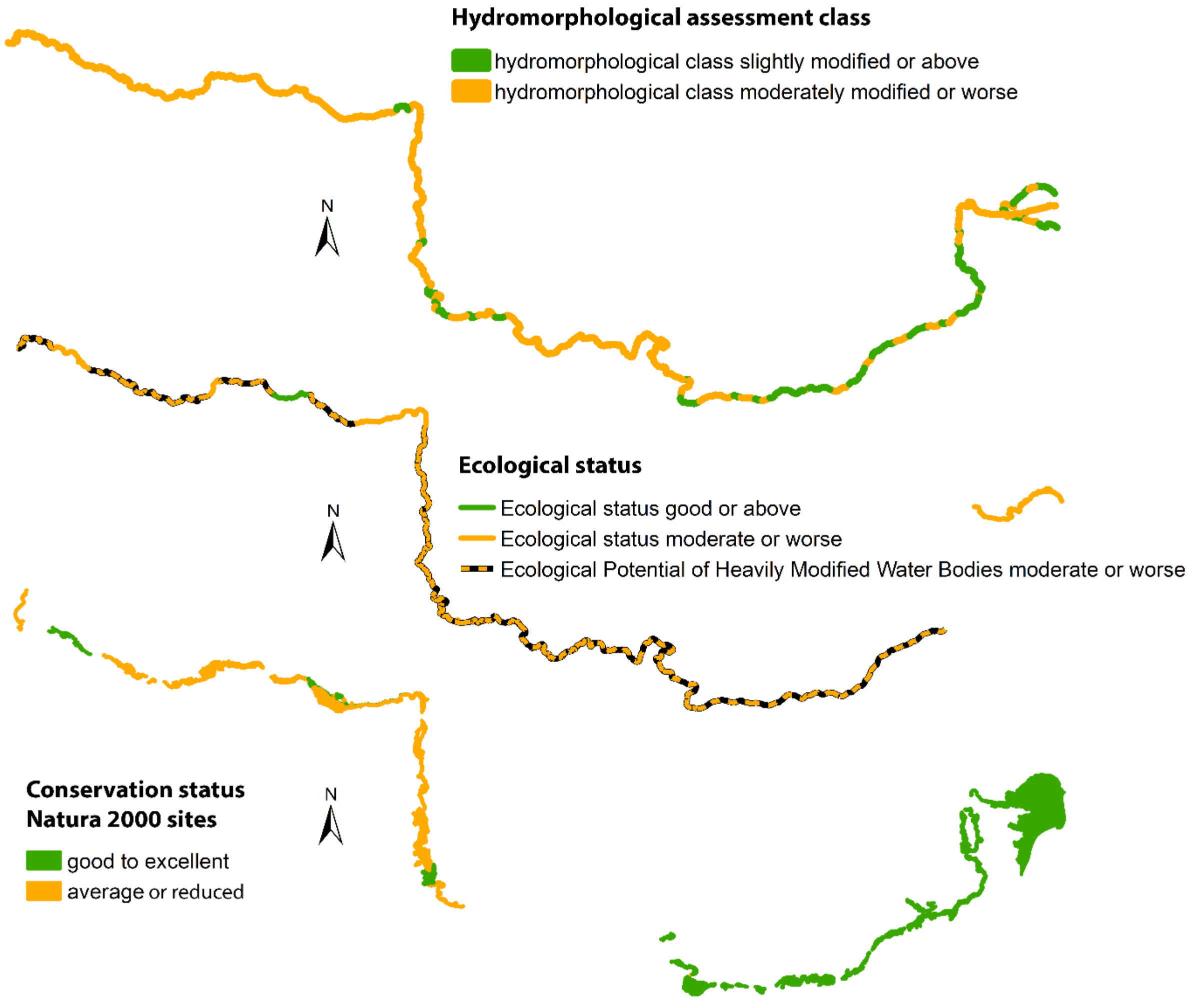


Figure 5: **Current situation**: Summary of the status of the navigable stretch of the river Danube based on upper graph: hydro-morphological assessment according to WFD (data from 2013) and middle graph: ecological status (WFD, data from 2015) as well as lower graph: conservation status of aquatic species in Natura 2000 sites (HBD, data from 2016).

To counter those deficits, hydro-morphological restoration of river-floodplain systems is defined as a measure of basin-wide importance to conserve biodiversity (EU Biodiversity Strategy to 2020, Target 2), ensure good status under WFD in the river stretch, flood protection, pollution reduction and climate adaptation by 2021 (chapter1 and 2, ICPDR, 2016a).

Those sites already proposed or planned for restoration based on national critera along the Danube main stem were defined as baseline scenario in our approach (**Baseline scenario,** ICPDR, 2016a). It is based on the national programmes of measures developed in the context of the implementation of the Water Framework Directive, which shall be made operational by December 2018 (ICPDR, 2016a).

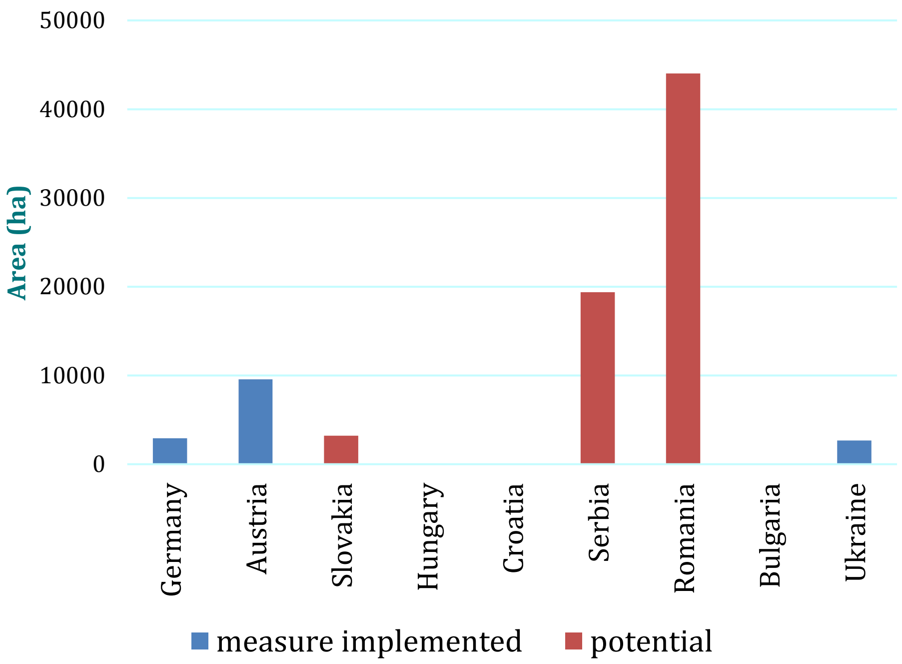


Figure 6: **Baseline scenario**: Area of wetlands and floodplains along the navigable stretch of the Danube that are already (partially) reconnected by 2015 or with reconnection potential where reconnection is foreseen (modified after ICPDR, 2016a).

4.2. Scenario development

Although there is already wide scientific evidence that reconnecting rivers with their floodplains is an effective measure to increase the ecological integrity, habitat availability for multiple species and the multiple functions and services of river-floodplain systems (e.g., Rumm et al. 2018, Mueller et al. 2017, Straatsma et al. 2017, Schindler, et al. 2014, Paillex et al. 2009, 2015, Reckendorfer et al. 2006), the selection of promising sites for restoration can be a demanding task. Complexity and heterogeneity of the environmental problems, lack of data and strong differences in socio-economic conditions along the Danube significantly hampers planning of restoration sites and few countries of the Danube region have already implemented or planned restoration until 2021 or even proposed sites with restoration potential. A large scale systematic prioritisation approach based on biodiversity and ESS targets is lacking. This is the aim of the spatial optimisation approach (**EBM scenario**, (see Funk et al. 2019) conducted within AQUACROSS using best available data related to biodiversity, ecosystem services, hydro-morphological alteration and the relevant drivers (see chapter 3.1.2 and 3.2.2 for more details) in line with EBM. This prioritisation method aims to support the selection of sites to be restored as it is based on optimised multiple biodiversity and ecosystem services indicators at the whole river basin level.

Therefore, we systematically prioritise restoration sites using a strategic modelling approach and compare our selection directly with the planning of the member states following the workflow illustrated in Figure 7.

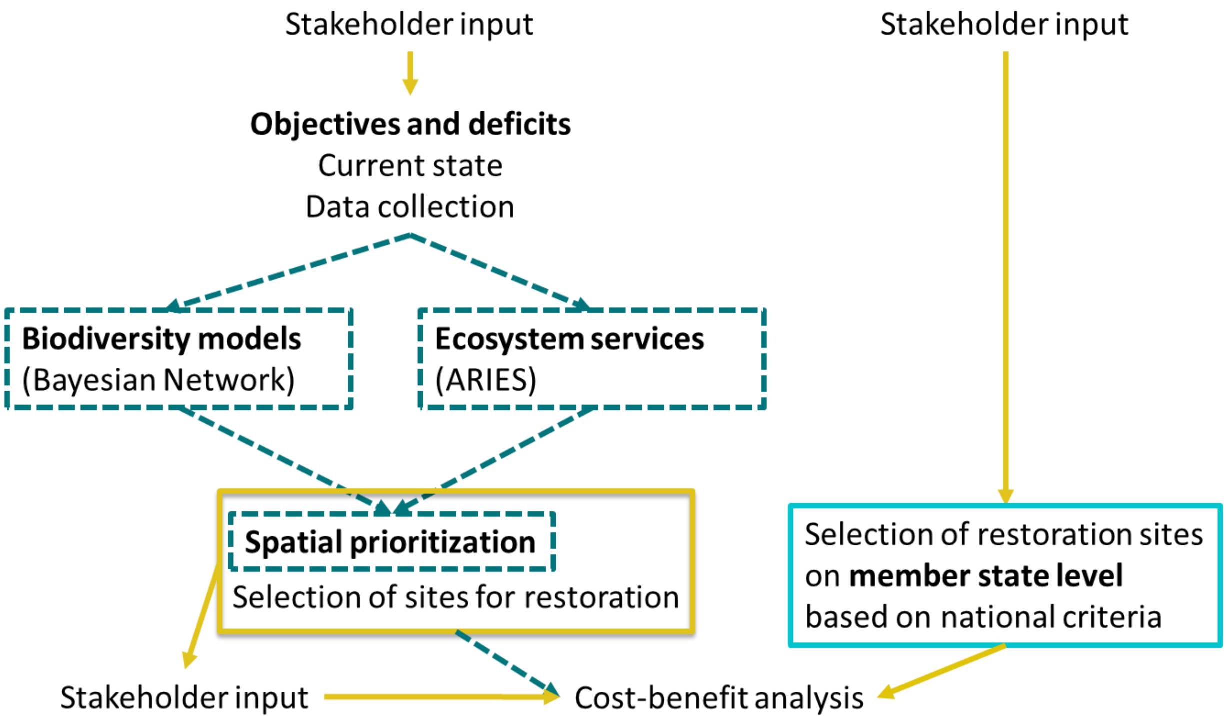


Figure 7: Workflow of model analysis (dark blue dashed) and scenario development (baseline in light blue, EBM scenarios in yellow) based on stakeholder input (yellow) for the Danube Case Study

In a first step, we modelled and predict relationships between 1) status indicators of biodiversity (expressed via local expert information on multiple aquatic species collected under HBD including fish, amphibian, birds and a mammal species) and essential ecosystem services i.e. flood retention (directly related to FD), crop pollination, which links directly to the importance of floodplains for agricultural production, and recreation potential, as an important service in the mainly urbanised and agricultural landscapes surrounding the Danube, 2) pressure indicators i.e., hydro-morphological alteration and 3) indicators on underlying drivers including land-use data and data on use for hydropower and navigation. Therefore, we modelled biodiversity indicators within a Bayesian network (BN) approach using the logic of the DPSIR framework and ecosystem services were quantified using the ARIES modelling platform.

In a second step, we calculated main factors relevant for conservation and restoration planning of river-floodplain systems, i.e. i) the remaining multi-functionality (river floodplain systems that provide habitats for multiple species as well as provision multiple ecosystem services) of the systems, ii) reversibility (potential to restore multi-functionality) related to multiple drivers and iii) the availability of remaining semi-natural land for restoration versus agricultural area.

In a third step, we made a spatial prioritisation based on trade-off analysis to identify important areas with biodiversity and ecosystem service restoration potential, by balancing for the three selected objectives for floodplain restoration i.e., increase multi-functionality of sites with deficits, restore sites with highest reversibility to increase probability for success and reduce costs and restore sites with highest availability of semi-natural areas to reduce loss of agricultural area and costs (see Funk et al. 2019 for more details).

Finally, we compare a selection of sites based on our approach with the planning of the member states. Outcomes of the Baseline and the EBM scenario will be assessed based on the environmental models presented and supplemented with a socio-economic analysis within a cost-benefit analysis. Differences of both strategies will are discussed based on the results (for more details see chapter 5).

5 Evaluation

5.1. Detailed specification of relevant EBM solutions

Within our trade-off analysis approach, we identified sites having restoration potential and either high reversibility or high availability of remaining semi-natural areas. These two objectives were balanced against each other within seven compromise scenarios ranging from optimised only for high reversibility to optimised only for high availability of semi-natural areas respectively. Our approach is very flexible as it is possible to combine the different compromise scenarios spatially based on varying socio-economic or political conditions, across regions or counties. For details on the methods see Funk et al. (2019) attached as Annex 4.

To get a representative example for the comparison with the baseline scenario out of the EBM scenario the selection of sites was based on the following criteria:

- Sites covering a total area of ~80,000ha (the same area that is covered in the Baseline scenario) were selected to make the two approaches comparable.
- Sites having the highest performance across all compromises were selected to get a representative set of sites for comparison out of the optimisation scenario.
- Floodplains were selected on site level and only sites of a size >500 ha were included. The threshold was defined according to the Danube River Basin Management Plan 2015.

Resulting site selection for the EBM scenario is described and compared to the Baseline in Table 1

What EBM plan do you propose?

Large scale restoration measures for river-floodplain systems aiming to reduce the direct effect of artificial structures like dykes, and levees on the hydro-morphological conditions of the system can be roughly classified into three groups:

- Re-flooding: Floodplains, isolated from the main river during large flood events by dykes, can be re-flooded due to removal, relocation, lowering, slotting or other alteration of dyke structures.
- Re-connection: Floodplains that are isolated from the main river can be re-connected to the main channel also during low water levels. This can restore natural dynamics

and erosion pattern of the system e.g. due to creation of bypasses, reconnection of floodplain channels, creation of secondary channels.

- Bank-restoration: Hard artificial material along the banks stabilising the position of the main stem can be removed totally or partially to allow the river to move laterally again within the floodplain.

Following a strict restoration strategy, we propose an intensity of restoration measures that removes the specified artificial structures so that only between 5 % and 15 % of the 10km stretches are left altered (see Schwarz 2014 for detailed definitions). This refers to the level that is defined as “good abiotic status” according to Birk et al. 2012. Only sites having a deficit (and therefore potential for restoration) related to this “abiotic status” of the selected indicators and were included for the evaluation.

The measures included in the EBM plan are “typical” floodplain restoration measures, for which only the area changes, in which the measures are applied. Principally, river floodplain restoration aims to return the system as close as possible to a near natural state to restore natural functions, provision of ecosystem services and ensure the sustainability of the ecological system (e.g. Palmer, 2005, 2014). As river floodplain restoration already takes place today (even though in different areas), it can be assumed that in principle all EBM criteria are met (e.g. technological and financial feasibility, ecologically sustainable, see Piet et al. 2018 for more details).

Table 1: Main differences between the baseline and EBM scenario

Main differences / communalities	Baseline	EBM *scenario*
Environmental ambition / policy target	The sites are listed in the DRBMP, which principally aims at reaching good ecological status/potential for all water bodies according to WFD.	Next to the targets of the EU WFD, the optimisation process considers also elements of the HBD, the Biodiversity strategy and FD.
Sites	Austria Donau-Auen östlich von Wien 9554 (ha) Slovakia Ramennasustavastaehokoryta Dunaja 3221(ha) Serbia Gornje Podunavlje19386 (ha) Romania Incinta Bistret-Nedeia-Jiu 16600 (ha) Romania Dabulen Potelu Corabia 14666 (ha) Romania Borcea Rau 11156 (ha) Romania Badalan 1593 (ha)	Austria Donau-Auen östlich von Wien, right bank 1500 (ha) Bulgaria Ostrov 2970 (ha) Bulgaria Ribanici orsoya 4800 (ha) Bulgaria Kalimok Bashlen 6600 (ha) Croatia Podunavlje i Donje Podravlje 7000 (ha) Hungary Gemenc 3430 (ha) Romania Incinta Bistret-Nedeia-Jiu 16600 (ha) Romania Danube Delta (outer part) 9470 (ha) Romania Dabulen Potelu Corabia 14666 (ha) Romania Lacul Suhaia 17300 (ha)

Main differences / communalities	Baseline	EBM *scenario*
Site selection strategy	Sites have been selected by national authorities. Site selection processes are based on national criteria as part of the national river basin management plans.	Sites are selected based on their potential related to effectiveness and efficiency of restoration measures. Modelling ensures the optimisation of these parameters and is the basis for site selection.

5.2. Setting the evaluation criteria

Co-Design

Evaluation criteria were set together with participants of a **workshop** on July 5th 2018:

- Feasibility, especially related to the **cost** factor is key for a successful restoration project. Restoration measures have first of all be affordable.
- Essential **ecosystem services** were identified that have to be considered. Beside **biodiversity**, **flood retention** and **recreational value** that are already taken into account in the prioritisation approach, stakeholders identified **nutrient retention** as another key ESS in the case study. Following the discussions, the service was included in the evaluation procedure.
- Urbanised areas are excluded as potential restoration areas. In contrast, the **reconnection** and **conversion of agricultural areas** into (semi-) natural restored floodplain areas should be a **target for restoration** as it increases ESS of the system.

Methods

Effectiveness: Impact of proposed restoration measures on **biodiversity** was directly predicted from Bayesian Networks for the multiple selected species. It was summarised as distance from the target -pristine conditions with full multi-functionality (a theoretical optimal point, i.e., 100% multi-functionality, see Funk et al. 2019) for each site.

Efficiency: Costs and benefits of restoration are estimated with insights from the literature on floodplain ecosystem services valuation and restoration costs. The main financial **costs** related to these measures are **investment costs.** These are mainly related to construction costs, though they also likely account for administration and planning costs. For re-connection, we use data from the US for side channel reconnection from Evergreen Funding Consultants (2003). For the next two groups of measures, we use the average of values reported in Deliverable 1.4 of the FP7 project REFORM (Ayres et al. 2014). We assume that re-flooding always implies dyke removal because it has the most cost estimates available, although dyke re-location or slotting are also plausible measures for re-flooding. Finally, bank restoration is removal of fixations or other hard artificial materials from the river bank. The main **economic cost** in both scenarios is the loss of arable land. For most countries we use the price of arable land to reflect the cost, since “in a competitive market, the price of land will equal the discounted sum of expected net returns (or utility) obtained by allocating the land to its most profitable use” (Plantinga et al. 2002). For Austria and Slovakia, due to a lack of information on land prices, we use information on yearly land rent, discounted at 4% over 30 years to approximate the cost. There is also an economic benefit derived from **foregone maintenance costs** for dykes and bank fixation, as they are being removed. To calculate the foregone maintenance costs for dykes, we use values from EEA (2017).

Beyond the input from stakeholder criteria, the analysis of **benefits** was based on a literature review (Schindler et al. 2014; Ayres et al. 2014; Brouwer et al. 2016). For the selected ecosystem services, the literature applied both stated and revealed preference methods for economic evaluation (Table 2). Cost replacement represents a revealed preference method as it calculates how much it would cost to replace the services provided by the ecosystem. Stated preferences are captured in the form of willingness to pay for an ecosystem service. We directly transferred the benefit values from the literature to the Danube case study.

Table 2: Criteria and methods for benefit calculation. CR: cost replacement, WTP: willingness to pay

Ecosystem services	Qualitative description of the changes in provision	Quantitative estimate	Approach	Methodology reference
Mediation services (nutrient retention)	Increased nutrient retention due to the replacement of cropland by natural land, and overall re-naturalisation of the floodplain	250-800 €/ha/year	CR	Schwarz (2006) based on literature values
Mediation services (nutrient retention)	Increased nutrient retention due to the replacement of cropland by natural land, and overall re-naturalisation of the floodplain	520-1540 €/ha/year	CR	Meyerhoff and Dehnhardt (2007)
Cultural ESS, recreation	Increased provision due to an augmentation of the sites naturalness (natural landscape, increased biodiversity, increased water recreation potential)	48-341 $/household/year	WTP	Brouwer and Sheremet (2017)
Flood protection	Increased provision potential for downstream population, due to the removal of artificial structures and thus increased water retention capacity in floodplains.	From 30 million € in the middle Danube (SK, HU), to 400 million in the lower Danube (RO, BG, MD, UA)	CR	Schwarz (2006), estimated damage costs from 2006 Danube floods
Flood protection	Increased provision potential for downstream population, due to the removal of artificial structures and thus increased water retention capacity in floodplains.	-0.02 €/household/year (Romania) to 0.13€/household/year (Austria)	WTP	Brouwer et al. (2016)

5.3. Results (Comparing scenarios/measures)

Priorisation within the EBM scenario

For the **results and validation of the prioritisation approach** see Funk et al. (2019) attached as Annex 4.

Within the EBM approach river-floodplain sections are prioritised for conservation or restoration all along the Danube. A gap analysis showed that approx. 80% of the area we were prioritising for conservation are already part of Natura 2000 sites. Some of the sites identified to have high restoration priorities are already designated as sites with high restoration potential or restoration is already ongoing (approx. 60% of baseline), and others were identified in areas where no sites are yet designated (adding approx. 3,000 km² of promising area). It also represents a traceable and flexible approach as the different objectives related to floodplain restoration are balanced systematically.

Evaluation

Overall calculated **effectiveness** of the management/optimisation scenario is significantly higher than for the baseline scenario ($p<0.05$, Mann-Whitney U Test). Most of the sites in the management scenario show lower distance to the target (Figure 7; distance to hypothetical target, i.e. 100% multi-functionality).

Costs are higher for the baseline scenario than for the management scenario (141m€ are estimated for the baseline scenario in comparison to 108m€ for the EBM scenario), as most of the restoration plans of the management sites are less costly (Figure 8).

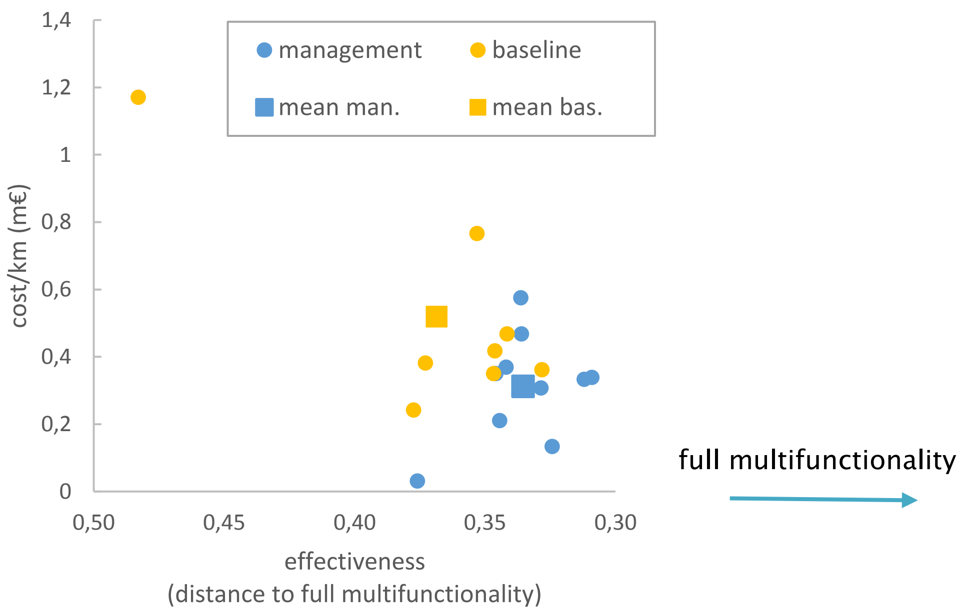


Figure 8: Effectiveness related to biodiversity and cost of restoration measures calculated for the different sites of the management and baseline scenario.

Altogether, the EBM scenario is showing a better performance than the baseline scenario, in terms of cost effectiveness. The lower costs are due to the optimisation model enables to select sites with an already higher level of naturalness. Those sites are thus easier to restore so that restoration measures require fewer investments and less loss of agricultural land.

Calculated **benefits** related to **ecosystem services** show a very high variability depending on the method of valuation selected. Therefore, there is some uncertainty about net benefits. Within our analysis, the two main parameters influencing the value of benefits are population density relative to the distance to site and the share of agricultural land in the restoration area. The second is smaller in the optimisation scenario so that the EBM scenario is expected to provide fewer additional benefits related to the naturalisation of agricultural land (e.g. nutrient retention, pollination). So if increasing the provision of ecosystem services related to naturalisation of agricultural land should be a priority for site selection, compromise results optimising only multi-functionality and reversibility instead of availability of semi-natural areas should be used for prioritisation. It should also be noted that the benefit analysis did not incorporate non-use values and that there are likely additional benefits in both scenarios from knowing that biodiversity is being protected (existence value), or from having the option to use protected resources in the future (option value).

Equity between countries is similar across the two scenarios. Both scenarios have a similar mix of upper, middle, and lower Danube sites: they each have one upper Danube site (Austria), and two middle Danube sites, and the EBM scenario has two more lower Danube sites than the baseline. Baseline sites fall in four different countries, with most of the cost burden falling on Romania and Austria, while the EBM scenario includes five countries, with Romania and Bulgaria bearing most of the costs, though Romanian costs are approximately €7 million lower in the EBM scenario than in the baseline. Restoration costs are generally financed at a national level and funding mechanisms can be important for ensuring that restoration takes place, especially for non-EU member states, which generally have more difficulty finding funding opportunities (ICPDR 2016a).

5.4. Pre-conditions for successful take off and implementation of EBM solutions

Within a case study workshop on July 5th participants generally appreciated the presented strategic prioritisation approach for floodplain conservation and restoration sites, especially as it has a broader focus and is not targeting the WFD alone which is often seen to be not very effective in the protection of floodplain systems.

The optimisation approach can support the selection of restoration sites including site proposals for the next DRBMP (WFD) or Flood management plan (FD) or can support the prioritisation of protected areas (HBD) for restoration measures at a local or regional level.

A practical example are the floodplain restoration plans led by viadonau, one of the key business stakeholders for the Danube case study, as it is leading different ongoing and planned integrative river restoration and engineering projects along the Danube. In a face to face meeting in August 2018 the systematic prioritisation approach was discussed and viadonau is interested in the integration of prioritisation results in a project proposal focusing on multiple floodplain sites along the upper and middle Danube to support the selection of relevant restoration sites. Therefore, AQUACROSS results have high potential to promote successful implementation of river-floodplain restoration targets along the Danube.

6 Discussion and Conclusions

We applied the AQUACROSS Assessment Framework to the river-floodplain systems of the Danube towards an ecosystem-based planning of conservation and restoration. We applied a systematic prioritisation approach, to establish an ecosystem-based management scenario and evaluate it in comparison to a baseline scenario developed for the River Basin Management Plan of the Danube.

Evaluation indicates the potential of the EBM scenario for better cost-effectiveness compared to the baseline scenario. It also represents a comprehensible and flexible approach as the different objectives related to floodplain restoration i.e., increase the multi-functionality, restore sites with high potential for reversibility and restore sites with high availability of semi-natural areas versus agricultural areas, are balanced systematically within different compromise scenarios.

Consideration of costs and benefits however tends to indicate that a site-specific exploration of the consequences of floodplain restoration on the local economic activities (especially agriculture and tourism) is required. In some sites, costs linked to restoration may require compensation of certain stakeholders through the use of policy instruments. This issue must be further investigated in the future. In this sense, the approach cannot replace local planning of specific projects but as a flexible large-scale planning tool it can support the integration across policies, targets and countries in line with EBM.

We increase the consideration of ecological integrity and biodiversity, accounting for multiple protected species and different relevant ecosystem services. Further, we consider cumulative impacts by multiple human activities including navigation and hydropower and components of the hydro-morphological pressures and integrate this multidisciplinary data and knowledge. Therefore, the prioritisation approach fosters integrated restoration planning across multiple policies by creating the opportunity to pursue different policy objectives simultaneously. It has a high potential to support the implementation of the EU Biodiversity Strategy (compare Hermoso et al. 2018, Cortina & Boggia, 2014). It is highly relevant for the measures to be proposed under EU WFD to reach “good ecological status” or “good ecological potential” and can support the prioritisation of sites for the next DRBMP. Results are also relevant for the Natura 2000 network along the Danube River (Hermoso et al. 2018), as restoration prioritisation can also guide the selection of sites for the funding of restoration projects within the network. Due to the inclusion of the ‘flood retention’ ecosystem service, it also has the potential to support the selection of sites for the EU Flood Risk Directive with respect to Natural Water Retention Measures (NWRM) and can support the next DFRMP.

The approach also has high potential to foster transboundary coordination and cooperation as it is considering the whole navigable main stem of the River Danube (ecosystem scale) independent from jurisdictional, administrative and political scales (e.g. country scale) and therefore has potential to foster consensus on a shared vision for the future. Beside the scientific basis of our approach, we also included input from stakeholders for the development and evaluation of the EBM scenario forming another central element of EBM.

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Annex

All annexes are available on the AQUACROSS website Case Study 3 page.

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