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Report

Imagining a Safe Water Space for Danube's Future
Engaging stakeholders for the co-creation of a Safe Operating Space for the Danube basin
November 22, 2023, Vienna, Austria

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[13 May 2024]

SOS Water

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ZVR 524808900

The authors gratefully acknowledge funding from European Union's Horizon EUROPE Research and Innovation Programme under Grant Agreement N° 101059264 (SOS-WATER). Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.

Abstract

On the 23 November 2023, the SOS-Water project held the first stakeholder workshop for the Danube Basin case study. As water challenges increase worldwide, exacerbated by climate change, the SOS-Water project aims to establish a Safe Operating Space (SOS) for water resources, to ensure an adequate, sustainable and clean water supply for both human activities and natural ecosystems. Funded by the European Union's Horizon Europe Framework Programme, the project uses an integrated approach that combines modeling, monitoring, and stakeholder engagement, applied to four different case studies in Europe and beyond. The Danube River basin, known for its ecological and socio-economic diversity, is one of the selected case studies.

The workshop convened key stakeholders from various freshwater-related institutions, promoting dialogue and collaboration to address the complex challenges that the basin is facing. During a day of interactive activities, stakeholders collectively identified values, objectives, and priorities essential for sustainable water management in both the entire Danube basin and the Danube Delta. Discussions underscored the need for integrated approaches that balance environmental conservation, socio-economic development, and climate adaptation.

Key outcomes include the refinement of objective hierarchy maps that reflect the stakeholder input and priorities collected during the workshop. The next steps will be the development of specific indicators for the objectives. This is followed by the weighting of goals (i.e., objectives) to be achieved through further stakeholder engagement activities and workshops, towards a co-development of the Safe Operating Space for the Danube River basin.

About the authors

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Acknowledgments

We are deeply indebted to the first Danube case study workshop participants. The stakeholders shared their valuable knowledge and insights about the Danube watershed. They actively contributed to developing an objective hierarchy that will guide the researchers' approach and modelling efforts to define a safe operating space for the Danube.

1. Introduction

1.1 Background

Significant increases in water withdrawals over the past century have been the primary cause of major environmental challenges around the world, including water scarcity, declining water quality and loss of freshwater biodiversity. In many parts of the world, climate and societal changes are expected to exacerbate these problems in the coming decades. There is an urgent call to action in alignment with the Sustainable Development Goals (SDGs) and the 2030 agenda. It is imperative to establish a safe operating space (SOS) for water resources, particularly in a dynamic climate and evolving societal landscapes, to ensure an adequate and sustainable supply of water meeting the quality standards for both human activities and natural ecosystems.

The SOS-Water initiative is a four-year project funded through the European Union's Horizon Europe Framework Programme for Research and Innovation, which aims to comprehensively assess and understand the status of the entire water resource systems. Coordinated by the Water Security Research Group of the International Institute for Applied Systems Analysis (IIASA), SOS-Water applies an integrated approach incorporating modelling, monitoring and development of advanced indicators and inclusive stakeholder engagement based on true collaboration. SOS-Water works with stakeholders in four case studies in Europe and overseas (Danube, Rhine, Jucar and Mekong basins) to co-create future scenarios and management pathways.

The results of SOS-Water will improve knowledge of water resource availability and improve water planning and management at local, regional and global levels. This will ensure equitable water distribution across societies, economies, and ecosystems, fostering resilience, social equity, and economic efficiency.

This report summarizes the discussions and conclusions of the first stakeholder workshop for the Danube case study, held in Vienna on 22 November 2023.

1.2 Danube case study

The Danube River is the second longest river in Europe, stretching ~ 3,000 km at its longest from Germany's Black Forest and the snow-capped Alps through the Hungarian plain and into the Black Sea. Covering approximately 800,000 km^2, the Danube is the largest river basin in Europe and the world's most international river basin, spanning over 19 countries with different cultural, political and environmental landscapes. Due to its size, the Danube basin is divided into three sections: the Upper (1,066 km), Middle (860 km), and Lower Danube (931 km; Figure 1), each with its own diverse ecological and socio-economic characteristics and are subjected to different environmental challenges. Annex 2 shows additional Danube basin maps, which highlight the river network, involved countries, sub-basins and their interconnections. The main stressors in the Danube basin concern water abstraction for irrigation and hydropower generation, navigation, pollution and the presence of invasive species.

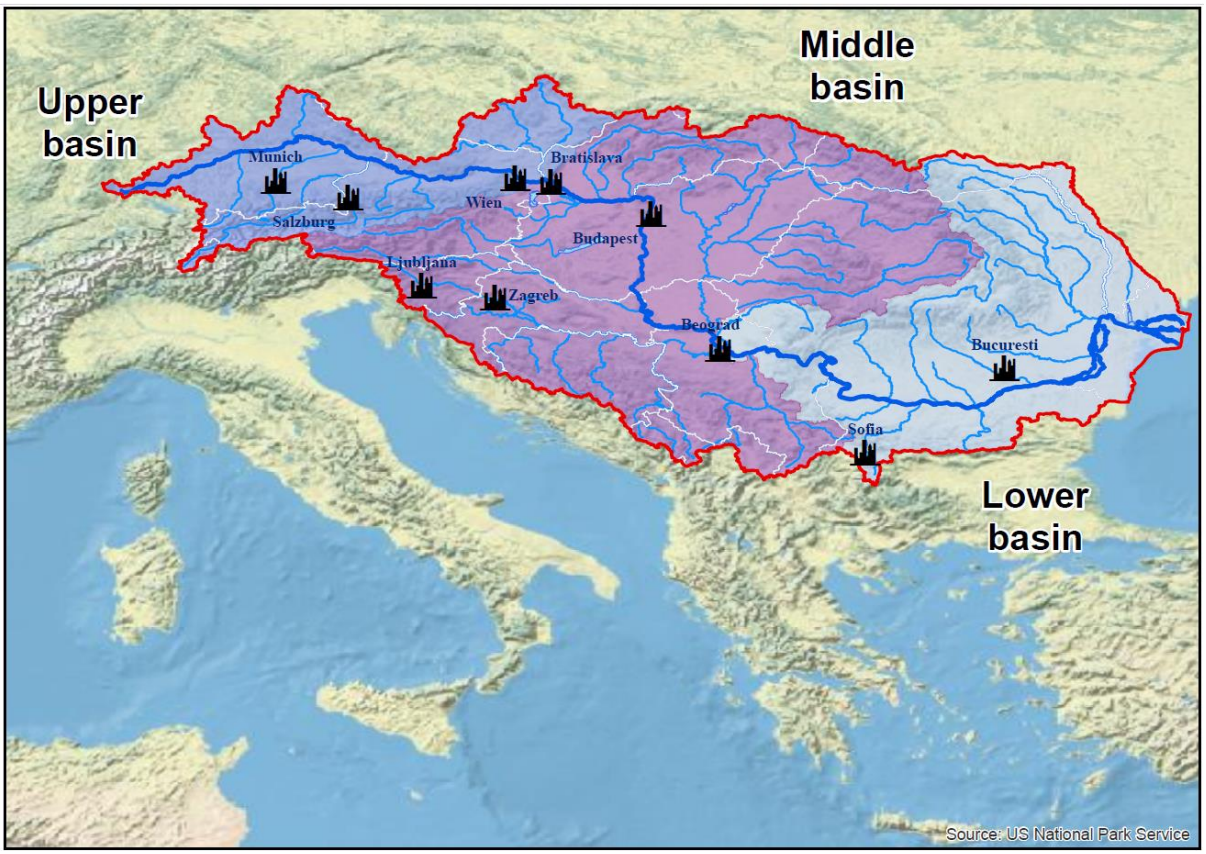


Figure 1. Danube basin map

In the SOS-Water project framework, the focus is, in addition to the entire Danube basin, also on the Upper and Lower basins due to their ecological characteristics and management challenges.

The Upper Danube is often acknowledged as Europe's primary water reservoir, with its significant hydropower potential and unique biodiversity spanning southern Germany, Austria, parts of Switzerland, and the Czech Republic. Its runoff regimes depend on snowmelt, and it is subjected to substantial regulation downstream due to transportation, settlements, agriculture, and hydropower exploitation. This leads to changes in environmental water supply, flood potential, sediment transport, and downstream flow, sparking conflicts over hydropower, agriculture, preservation, and tourism.

The Lower basin comprises the Danube Delta, which is formed by the outlet of the river flowing into the Black Sea in Romania. The Danube Delta is an essential European wetland, a unique and vulnerable natural habitat hosting diverse fauna and flora. Activities regulated upstream, such as energy production and agriculture, alter downstream flood regimes, sediment transport, and water quality, producing cumulative impacts in the Delta region. Current efforts to counteract sediment loss through channelization unintentionally contribute to pollution, eutrophication, and coastal erosion, highlighting the complexity of this region. Conflicts exist between upstream energy and agricultural interests and environmental protection, tourism, and downstream local communities.

Key stakeholders representing all relevant water sectors for the Danube basin and three stakeholders for the Danube Delta expressed interest in participating in our stakeholder engagement process. Those stakeholders

will collaborate closely with scientists from IIASA and other partner institutions to design an SOS framework for the Danube basin.

2. First stakeholders' workshop for the Danube case study

2.1 Workshop objectives

The stakeholder engagement process's main objective is to establish an ongoing dialogue involving all significant interest groups related to freshwater in the Danube basin. The purpose is to collectively identify local water challenges, as well as the needs and preferences of stakeholders. The insights gained from this engagement will be directly incorporated into formulating the SOS-Water framework. Over four years, the culmination of this collaborative dialogue will result in a case-study-specific SOS-Water framework, which aims to illustrate diverse water futures depending on water allocations to human water use and the environment to support healthy ecosystems and ecosystem services.

The workshop was structured as a one-day event comprising several activities (see Annex 1: Agenda) aimed to achieve the following expected outcomes:

- Initiate a dialogue between the leading key players in the Danube basin
- A shared understanding of the main challenges faced by the Danube basin
- Identification of the stakeholders' values
- Identify specific objectives and define an objectives hierarchy map for the Danube basin

Being the first workshop, we also aimed to introduce the SOS-water project and available methods and modelling resources relevant to the Danube case study, as well as to set the scene for a long-term collaboration between our project partners and key stakeholders of the Danube basin.

A total of 29 people from 5 countries attended the workshop, including the organizers. Stakeholders represented a wide range of freshwater-related institutions listed in Table 1.

Table 1. List of institutions participating

International Commission for the Protection of the Danube River (ICPDR)
National Agency for Land Improvements (ANIF)
International Association for Danube Research (IAD)
Danube Delta Biosphere Reserve Administration (ARBDD)

Danube Commission
International Institute for Applied Systems Analysis (IIASA)
Federal Ministry of Agriculture, Forestry, Regions and Water Management (BML)
Eutema Research Services
Viadonau
University of Natural Resources and Life Sciences (BOKU)
Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB)
Norwegian Institute for Water Research (NIVA)
International Association of Water Service Companies in the Danube River Catchment Area (IAWD)
European Landowners' Organization (ELO)
Verein fur Okologie un Umweltforschung (VÖU) / Tiwag
Wolff Environmental Consulting (WEC)
World Bank
The National Institute for Research and Development of Marine Geology and Geoecology (GeoEcoMar)
The Danube civil society forum

2.2 Introduction of stakeholders

Participants were invited to write their name, institution, and the role of their institution in the Danube on post-its and briefly introduce themselves to the audience. This activity helped set the overall mood and created a welcoming atmosphere, encouraging networking and the exchange of ideas, emphasizing the collective commitment to the sustainable development and preservation of the Danube River basin.

2.3 Multi-Criteria Decision Analysis (MCDA) Methodology

To ensure a thorough and inclusive stakeholder engagement process, the SOS-Water project utilized the Multi-Criteria Decision Analysis (MCDA) method[1]. MCDA deals with complex decision situations characterized by diverging values, interests and objectives of different groups. One of the main advantages of MCDA is that it systematically breaks down these complex scenarios into transparent and manageable components. At the same time, it recognizes the presence of subjective preferences (i.e. people's opinions), while emphasizing the importance of distinguishing these preferences from data-driven model outputs and predictions.

In using MCDA, we adopt a step-by-step guidance approach (Figure 2). This involves guiding critical stakeholders through the decision-making process, promoting social learning and ultimately facilitating the discovery of shared solutions. The method acts as a bridge between different perspectives, creating a structured framework that encourages collaborative decision-making. This, in turn, ensures that the decision-making process is transparent, manageable, and conducive to achieving consensus among stakeholders with different values and goals.

In MCDA, the objectives identified together with the stakeholders are organized in a hierarchy of goals and sub-goals that reflect the stakeholders' values. Dividing objectives into sub-objectives facilitates the identification of priority actions, as stakeholders define the relative importance of sub-objectives by assigning weights to them, and the assignment of indicators, i.e. measurable system attributes.

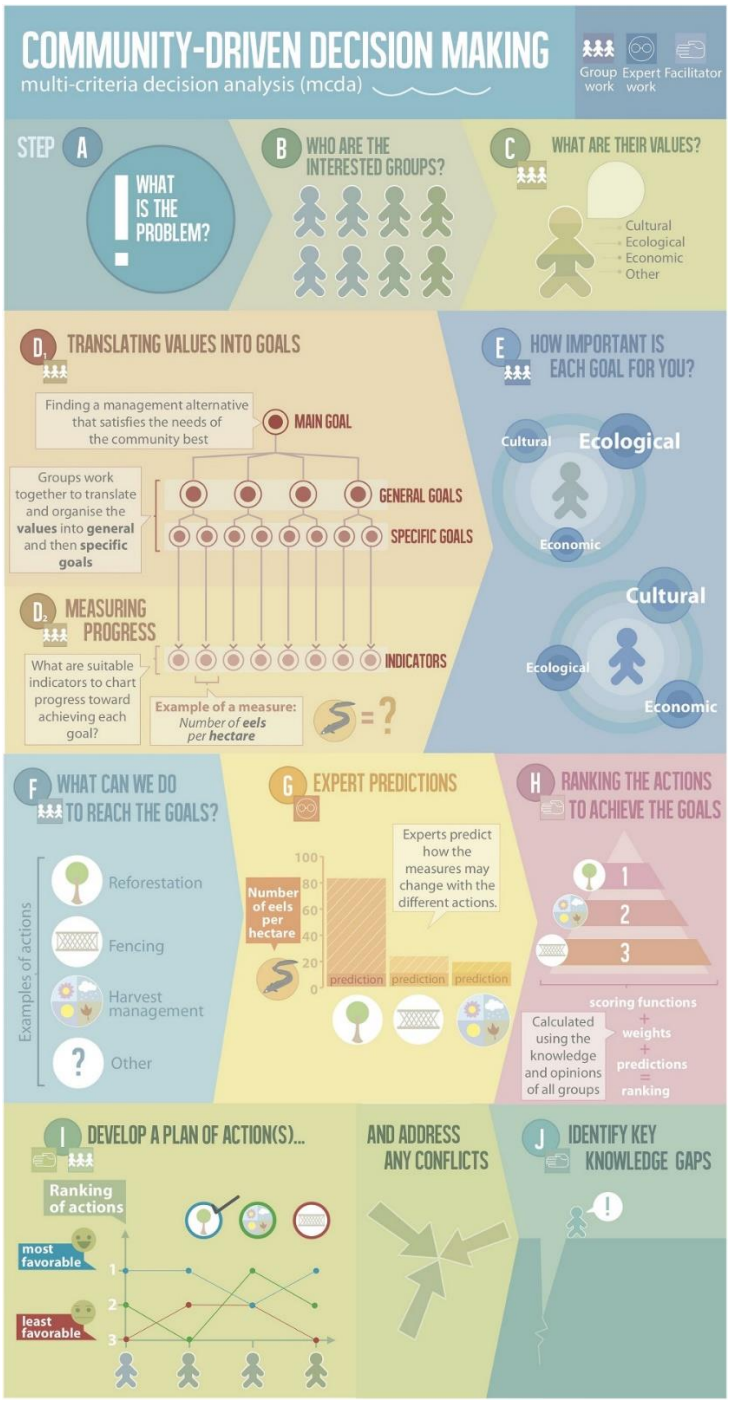


Figure 2. Step-by-step guide to the stakeholder engagement process, Langhans et al. (2019).

[1] Langhans, S. D., Jähnig, S. C., & Schallenberg, M. (2019). On the use of multicriteria decision analysis to formally integrate community values into ecosystem-based freshwater management. River Research and Applications, 35(10), 1666-1676.

In this first workshop, activities were designed to favor interactive engagement and thus the time for presentations was restricted to the first hours of the morning. In this time frame, we introduced participants to the subject of the workshop and the SOS-Water project. We illustrated the status of the hydrological, biodiversity, and ecosystem services modelling. Then, we presented the engagement method (MCDA) and concluded with an overview of the project concept.

Task 1: Individual identification of stakeholder values

Stakeholders were invited to write on some post-it their institution's values, objectives, and benefits for the Danube River (see text box).

Workshop task 1: Specific questions

- *What are the water-related values of the Danube River Basin your institution stands for?*
- *What are the benefits provided by the Danube your institution is interested in?*
- *What objectives would you like to see achieved for a safe operating space in the Danube?*

Two maps illustrated the Danube basin, one for the whole catchment, and another separated into Upper, Middle, and Lower basins (Figure 3). Stakeholders were asked to read their post-it to everyone and attach them on the maps where relevant (i.e., relevant only at the local level or for the whole basin).

Figure 3. Photo from the first task of the workshop

Task 2: *World Café* for objective hierarchies using the identified values/objectives

A tentative objectives hierarchy map was presented to the participants (see Annex) and discussed in depth in three groups with a World Café arrangement (Figure 4). Based on the outcome of the previous exercise, two tables were set up for the whole Basin and one specific for the Danube Delta. Each table had a facilitator and a note taker from the organizing team, explaining the map and facilitating discussions that centered on refining the existing objectives hierarchy. This was done by asking stakeholders to identify irrelevant objectives and suggest important additions. After 30 minutes, stakeholders were invited to swap tables and freely join the discussion at other tables.

Figure 4. Photo from one of the tables during the World Café

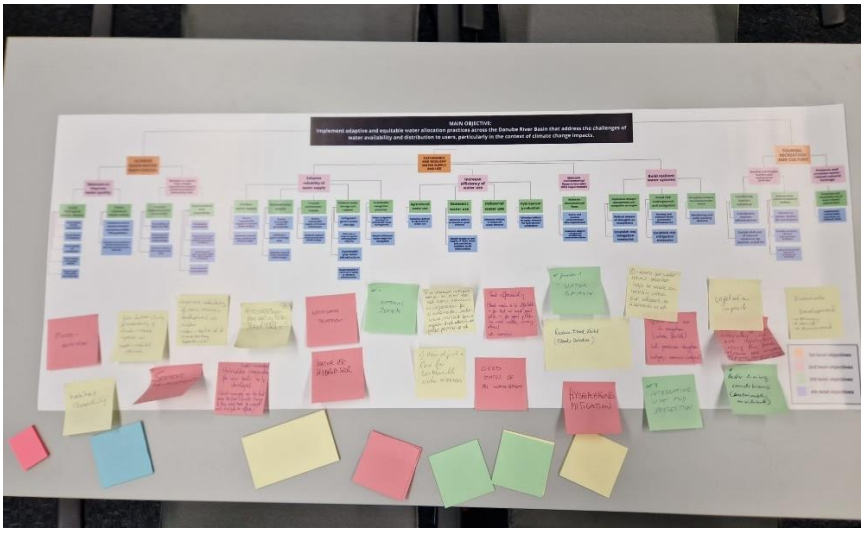


Figure 5. Example of one of the objectives hierarchy maps after stakeholders' inputs

Task 3: Reporting back to everyone

The facilitators reported what was discussed during the World Café to the whole group.

3. Results and discussions

Stakeholders responded positively to the workshop and the scheduled activities, actively engaging, and contributing to the discussions.
The process began with participants sharing their key values for the Danube basin. This discussion then formed the foundation for developing an objectives hierarchy. Due to time constraints, the SOS-Water researchers developed draft objectives hierarchies, one for the Danube Delta and one for the Danube basin. The stakeholders used these draft hierarchies as a starting point for their discussions.

3.1 Values

The stakeholders identified values, objectives, and benefits for the Danube River and Watershed (see Figure 5 and Annex 4). The most frequently repeated themes across the identified values, objectives, and benefits included environmental protection, climate change adaptation, food availability and affordability, water quality for agriculture, transboundary cooperation, and sustainable water resources management. These values, objectives, and benefits collectively call for an integrated and sustainable approach to water management in the Danube Delta and the entire catchment area, which integrates environmental, social, and economic aspects, stakeholder involvement, and compliance with regulatory frameworks.

Figure 6. Danube basin Map with the post-its from the first task, listing stakeholders' values, objectives and benefits for the basin

3.2 Whole Danube Basin

A preliminary objectives hierarchy map was introduced to participants and thoroughly explored through three World Café-style discussion groups. Two of these groups specifically focused on the whole Danube Basin, where stakeholders emphasized several points of significance.

Both groups highlighted the importance of groundwater as it plays a key role in sustaining various ecosystems and human activities, but which is often overlooked in favor of surface water. Also, in the Danube basin, historical emphasis on water quality needs to balance with increasing concerns about water quantity due to climate change.

Guided by stakeholder feedback from the first workshop, the SOS-Water project will adopt a sustainability and resilience-focused approach to enhance water security within the Danube region. Our approach should provide a clear action plan and revolve around the three main aspects of water management in the Danube River basin: environment, society, and economy. Climate adaptation and preparedness should be integral parts of our approach, including stakeholder cooperation. Furthermore, strengthening connections among people, progressing from the regional to the local level, is essential towards a more integrated approach. The Framework for Water Development (FWD) should act as the umbrella for all objectives, providing a cohesive framework for our initiatives.

Two highlighted points are the need for a comprehensive understanding of water uses and the importance of managers having effective tools to tackle issues. Authorization in water use requires improvement, as it often does not consider the availability of water resources, especially in the context of rainfed agriculture, where water use is not quantified. The recent six-week navigation blockage due to insufficient water release by Bulgaria highlights the need for adaptation in the logistics system in the Danube. Surprisingly, there is a lack of integrated studies regarding navigation water availability in the Danube Basin. Also, it is unknown how upper Danube reservoirs influence water levels in the basin. Two new objectives are proposed, which are "improve efficiency of water use between the different users" and "have a good prioritization of water use". Water allocation, determining who gets priority (e.g., prioritizing the environment in scenarios like water scarcity for system resilience and sustainability) is thus an important point in water management and should be related to functional sectors, not to administrative regions. Water allocation needs to be aligned on the local level to be able to engage in the regional and international level (downstream/upstream of the basin). The concept of a "fair share" for the Danube basin is also proposed.

Stakeholders recommend refraining from using the term "restore" for river-related connectivity targets, opting for "revitalization" instead, as restoration goals are only ecological while revitalization has also social and economic goals and is thus more desirable. The discussion points out missing elements in the map, such as vertical connectivity, and the use of water for cooling systems as in nuclear power plants, which could be classified under energy production. Other issues connected to water management that emerged from the discussion were sediment management, flood protection and potential conflicts for water from resource shrinking.

These gaps highlight the need for comprehensive research and an integrated approach in the Danube basin that considers not only environmental aspects, but also the societal and economic dimensions of water management.

3.3 Danube Delta

The Danube Delta forms the outlet of the Danube River flowing into the Black Sea. Most of the delta lies within Romania (Tulcea County), but some of its northern fringes are in Ukraine (Odesa Oblast). It is a unique and vulnerable natural habitat consisting of various river branches, channels, flood plains, and lagoons. Upstream water management, energy production, and agricultural activities across the entire basin alter downstream flood regimes, sediment transport, and water quality, leading to a broad range of aggregated impacts in the delta region.

Today, the entire region of the Danube Delta has one or several designation statuses partly overlapping, including:

i) Unesco 'Danube Delta Transboundary Biosphere Reserve, Romania/Ukraine', designated since 1998, 732,219 ha; see https://en.unesco.org/biosphere/eu-na/danube-delta

ii) Ramsar Site, Wetland of International Importance, Danube Delta Ramsar Site, designated in 1991, 647,000 ha, see https://rsis.ramsar.org/ris/521

iii) Danube Delta Biosphere Reserve in Romania, established in 1990, is one of 16 protected areas along the Danube River, organized by the DANUBEPARKS association, see https://danubeparks.org/

iv) Unesco-MAB (Man and the Biosphere Programme): Danube Delta, established in 1998, 580,000 ha (82% terrestrial, 18% marine); see https://www.unesco.org/en/mab/danube-delta

The Danube Delta is home to a rich mix of Bulgarian, Gagauz, Lipovan, Moldavan, Russian, Turkish and Ukrainian people scattered around the delta in small villages. The main economic activities in the biosphere reserve are fishing, hunting, reed harvesting, livestock raising, subsistence agriculture, and tourism.

Discussion points

Stakeholders highlight that the entire Danube Delta today has some nature conservation protection status. A key challenge is aligning people's activities in the Delta with management objectives aligned with nature conservation. Tourism should have strict regulations related to sustainability and protection of the biosphere. Boats with motors should be under strict regulation and, in some areas, discouraged.

There has been vastly increased traffic of cargo ships using branch rivers of the Danube since the Russian invasion of Ukraine. Lacking safe passage through the Black Sea, Ukraine must export grain almost exclusively via its Danube River ports. This development brings potential economic benefits and efficient transportation

opportunities, but the current traffic is beyond the capacity and expectations of current policies. Policies and regulations to protect and benefit from the increased traffic need to be addressed immediately.

The Danube Delta, renowned for its rich biodiversity and unique ecosystem, faces significant threats stemming from upstream activities and agricultural practices. Upstream dams and reservoirs withhold vital sediments that would naturally replenish the delta's intricate wetlands, disrupting the delicate balance of sedimentation and erosion processes essential for sustaining its dynamic landscape. This sediment deprivation not only affects the Delta's morphology but also jeopardizes the habitats of countless plant and animal species.

Furthermore, agricultural runoff laden with pollutants poses a pervasive threat to the health of the Danube Delta. Pesticides, fertilizers, and other chemicals used in upstream agricultural areas find their way into the river system, eventually reaching the Delta. This influx of pollutants contaminates the Delta's waterways, impacting water quality and threatening the survival of aquatic life. Additionally, nutrient runoff fuels algal blooms, which can deplete oxygen levels in the water, leading to fish kills and further ecological imbalances.

The Iron Gate contributes to flood control but causes lateral and longitudinal disconnection.

While the Delta may lack significant economic value, tourism is still highly important. Objectives must be reframed to align with the project goal of efficient, resilient, and sustainable water management, emphasizing water services delivery, water related risk mitigation, and water resource management.

Addressing these challenges is crucial for safeguarding the Danube Delta's biodiversity and ecological integrity. Implementing sustainable land management practices upstream, such as soil conservation measures and agroecological approaches, can help mitigate sediment retention in reservoirs and reduce agricultural runoff pollution. Collaborative efforts involving local communities, governments, and environmental organizations are essential to ensure the long-term health and resilience of this natural treasure.

3.4 Some outcomes from the workshop: New objectives maps

Based on the results from the workshop, the objectives hierarchy's maps for the Danube Basin and the Danube Delta were redefined to integrate the insights given by the stakeholders (see Annexes 5 and 6).

For the Danube River Basin as a whole, a new main objective has been defined: "Enhance and sustain the socio-economic and ecological resilience of the Danube River Basin, particularly in the context of climate change". This title incorporates some of the suggestions from the SH, such as the emphasis on the resilience of the system and its social, economic and environmental components.

Eight new upper-level objectives have been created, with a particular focus on maintaining the function of freshwater systems (see Annexes 5 and 6):

- Maintain and/or improve regulatory water functions;
- Maintain and/or improve water storage functions;
- Maintain and/or improve water supply functions;

- Maintain and/or improve productive water functions;
- Maintain the Basin's ability to transport and process chemical loads;
- Maintain healthy functioning of ecological communities;
- Adapt to climate change and build resilience;
- Enhance governance for sustainable water management.

For the final two main objectives, we took into account the input from our stakeholders regarding the importance of stakeholder cooperation and connecting people from the regional to the local level, as well as a focus on climate change adaptation and governance. These objectives emphasise the importance of stakeholder participation, cross-border cooperation and the establishment of platforms and programmes for best practice and data sharing, as well as assessing the vulnerability of water-dependent ecosystems and sectors, and establishing proactive plans for managing droughts and floods.

Groundwater, which was included in the previous map only in relation to supply, is now taken into account also for its water quality, storage function and productive function to sustain groundwater-based terrestrial ecosystems.

Tourism, recreation and cultural activities, which were included in a high ranking objective in the previous map, are now included under the maintenance and improvement of water supply functions and more specifically in the objective related to maintaining sufficient water availability for diverse needs, together with sustainable navigation practices, safe and reliable domestic water supply, and use of water for industry and hydropower.

The map for the Danube Delta follows the same structure, but with some differences from the one for the whole Basin, based on the feedback from the stakeholders (e.g., less concern regarding water storage and groundwaters, a greater focus on securing enough water for irrigation, aquaculture/fishing tourism etc.).

Following these, the Danube Delta includes a greater focus on reconnecting freshwater lakes with marine systems, ensuring equitable access to and the sustainable use of water resources by fishing activities and fishing-based tourism, maintaining and/or enhancing the natural filtration capacity of wetlands and riparian zones to filter pollutants and improve water quality and the establishment and sustainable management of biosphere reserves.

4. Next steps and outlook

The ongoing project is running until September 2026. Two to three other workshops are planned as a follow-up where stakeholders and project members will co-develop objectives and priorities for the Danube Basin and discuss the applicability and improvement of the SOS-Water framework.

The next steps are:

- Publication of this workshop report on the IIASA's publication repository PURE with access links to download the PDF presentations of the workshop (April 2024);

- One-on-one online meetings with each stakeholder to present the new objectives maps, collect first feedback, and gather stakeholder input on the relative importance of each objective (weight elicitation) (Summer 2024);
- Identification of indicators to measure the progress of each objective identified in the maps (Autumn 2024);
- Preparation of the second stakeholder workshop to establish value functions in collaboration with stakeholders, and elicit their risk behaviors (November 2024);
- During the third stakeholder workshop, outcomes from the project and stakeholder engagement will be shared will the stakeholders, facilitating discussions around insights and findings, with the aim of refining the SOS-Water framework and optimizing management plans (tentatively scheduled for Autumn 2025);
- In the fourth and final workshop, the adapted SOS-Water framework and fine-tuned spatially optimized management plans will be presented to the stakeholders, along with exploring possibilities for ongoing partnerships and collaborations (tentatively scheduled for Spring 2026).

ANNEX

Annex 1: Detailed Agenda
Annex 2: List of institute participants
Annex 3: Tentative objective hierarchy for the Danube Basin
Annex 4: Results from workshop Task 1
Annex 5: New co-designed objective hierarchy maps for the Danube Basin
Annex 6: New co-designed objective hierarchy maps for the Danube Delta

Annex 1: Detailed Agenda

SOS-Water
Stakeholders' Engagement 1st Workshop

Wednesday 22nd November 2023, Vienna
Venue: Your office - Room Rhein (1st floor), Europlaza, Am Euro Platz 2, 1120 Wien

Agenda

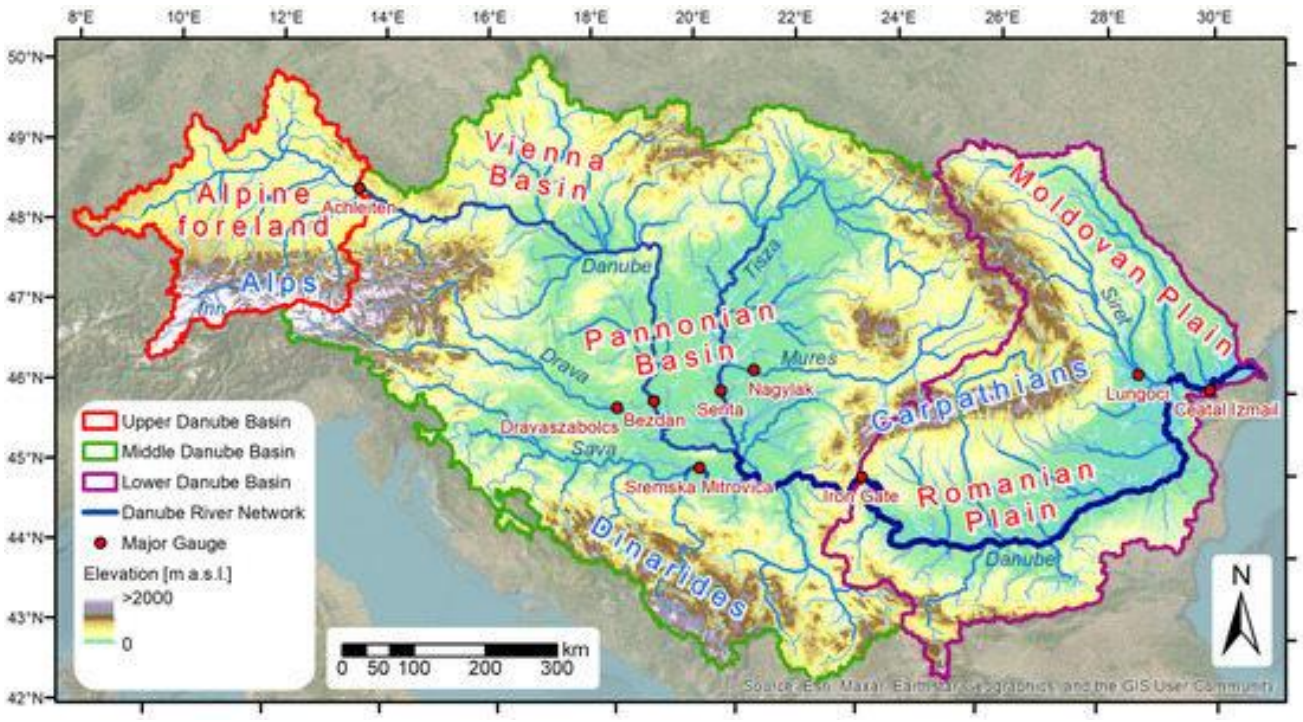
From	To	
9:00	9:15	Registration and welcome coffee
9:15	9:30	Official welcome and participant introduction
9:30	9:45	SOS-Water project presentation
9:45	10:25	Multicriteria Decision Analysis method presentation
10:25	10:40	Water resources models of the Danube
10:40	10:55	Biodiversity and ecosystem services models
10:55	*11:15*	*Coffee break*
11:15	11:35	Project concept and workshop introduction
11:35	12:35	First task: identification of stakeholder values
12:35	*13:30*	*Light Lunch*
13:30	15:00	Second task: definition of objectives hierarchy
15:00	15:30	Final discussion and outlook

Task	Time required	From - to
Registration and coffee	15-30 min	09:00 – 09:15
Stakeholder introduction	15 min	09:15 – 09:30
Introductory presentation (SOS-Water intro)	10 min	09:30 – 09:40
Q&A	5 min	09:40 – 09:45
MCDA presentation	30 min	09:45 – 10:15
Q&A	10 min	10:15 – 10:25
Water resources models of the Danube	10 min	10:25 – 10:35
Q&A	5 min	10:35 – 10:40
SDM/ES models	10 min	10:40 – 10:50
Q&A	5 min	10:50 – 10:55
Break	20 min	10:55 – 11:15
Project concept	10 min	11:15 – 11:25
Workshop introduction	10 min	11:25 – 11:35
First workshop task: individual identification of stakeholder values	45 min-1 h	11:35-12:35
LUNCH	55 min	12:35-13:30
Second workshop task: World cafe	1 h	13:30 – 14:30
Third workshop task: Stakeholders reporting back	20-30 min	14:30 – 15:00
Final discussion and future outlook	15 min	15:15 – 15:30

Abbreviations: OH: objectives hierarchy; SDM: Systems Dynamic Models; ES: ecosystem services.

Annex 2. Danube basin maps

Danube Basin river network, and the sub-division into Upper, Middle and Lower Danube

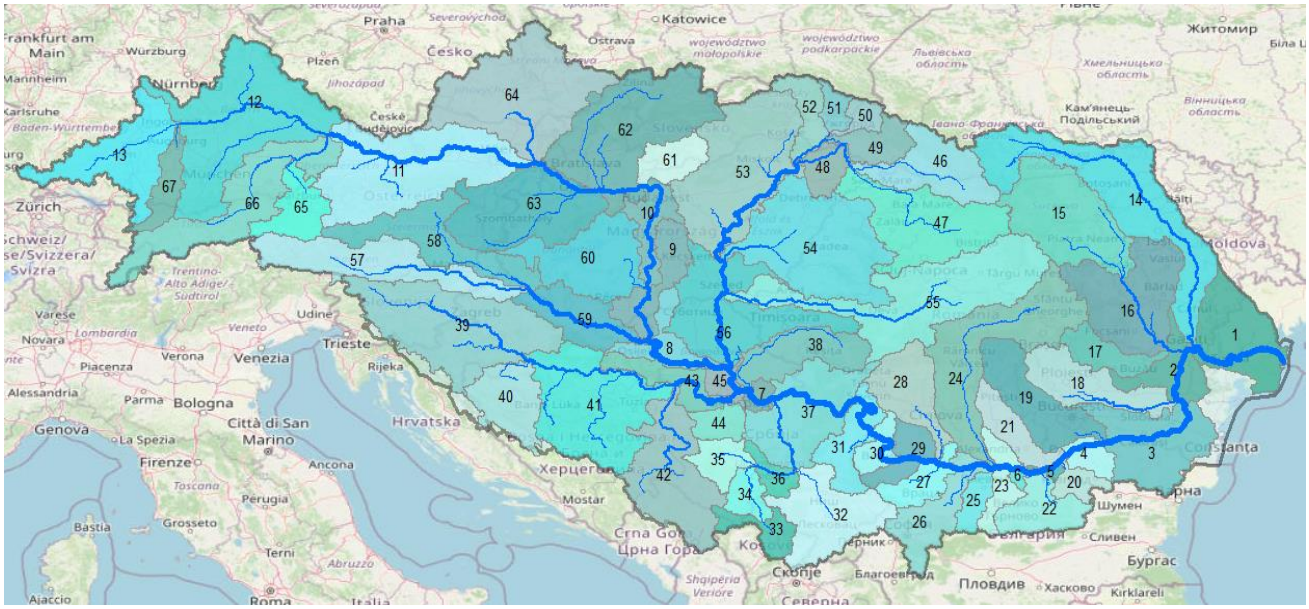


Source: Probst and Muaser 2023, ICPR, ESRI

Danube River Basin with its countries

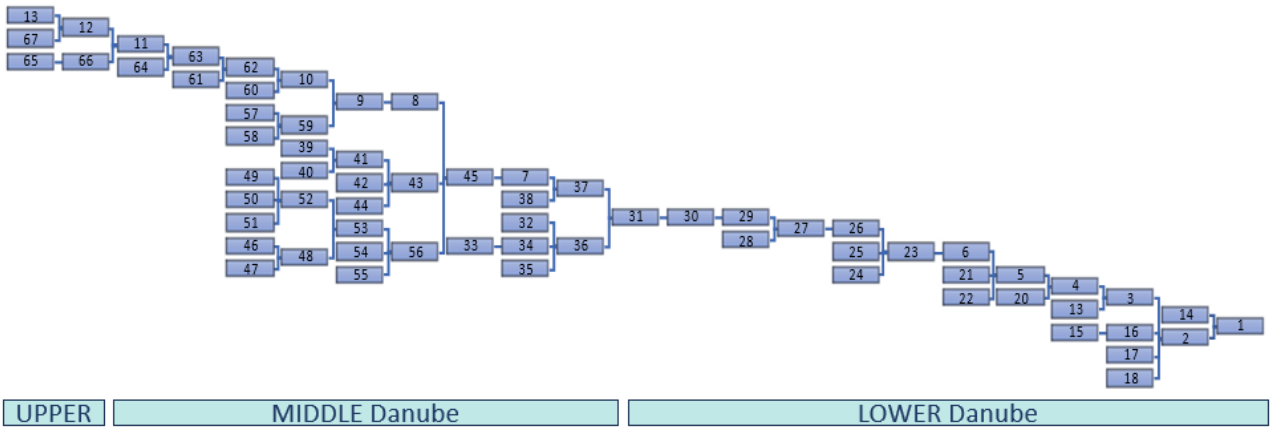
Source: International Commission for the Protection of the Danube River (ICPDR)

Danube River Basin with its subbasins



Source: HydroSheds, OpenMap

Danube river network connection of subbasins

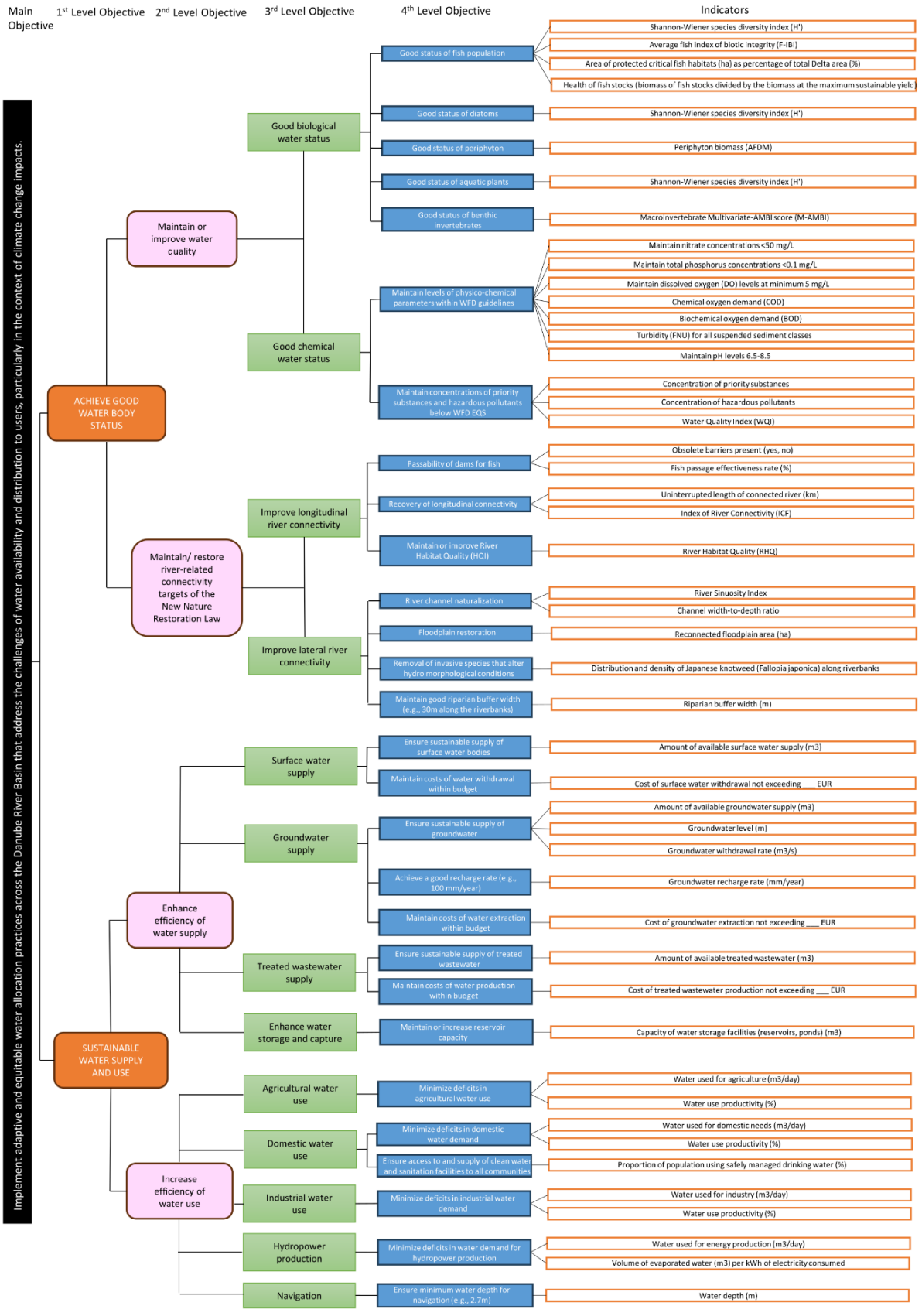


Source: CWatM based on HydroSheds and OpenMap

Danube River, Sub-basins

No	Subbasin	No	Subbasin	No	Subbasin
1	Danube Delta	23	Osam	45	Sava 4
2	Danube 12	24	Olt	46	Tysa
3	Danube 11	25	Vit	47	Somes
4	Danube 10	26	Iskar	48	Tysa 2
5	Danube 9	27	Ogosta	49	Latorica
6	Danube 8	28	Jiu	50	Uzh
7	Danube 7	29	Lom	51	Laborec
8	Danube 6	30	Archar	52	Bodrog
9	Danube 5	31	Timok	53	Tysa 3
10	Danube 4	32	South Morava / Nisava	54	Crisul Repede/Alb
11	Danube 3	33	Sitnica / Drenica / Lab	55	Mures
12	Danube 2	34	Ibar	56	Tisza
13	Danube 1	35	Rzav / Moravica Morava	57	Druu
14	Prut	36	Zapadina Morava	58	Mura
15	Bistrita	37	Great Morava	59	Drava
16	Siret	38	Tamis	60	Lake Balaton
17	Buzau	39	Sava 1	61	Ipel
18	Ialomita	40	Una	62	Vah
19	Arges	41	Sava 2	63	Ruba
20	Beli Lom	42	Drina	64	Morava
21	Vedea	43	Sava 3	65	Salzach
22	Yantra	44	Kqubara	66	Inn
				67	Lech

Annex 3: Tentative objective hierarchy for the Danube basin



Annex 4: Results from workshop Task 1

First task: Stakeholders write down on Post-its their institutions' values, benefits and objectives for the Danube and place them on a map of the Basin. The summary below does not include repetitive values/benefits/objectives.

Whole Danube basin

Values:

- Water use hydropower
- Management of fisheries
- Include all stakeholders
- Better living conditions (food production and food security)
- Habitat availability
- Habitat connectivity
- Vegetation impacts (floods, all vegetation that prevents rivers from eroding)
- Secure and good navigation status and port infrastructure
- Safe ecological status
- Rich biodiversity
- People capital
- Drinking water
- Sustainable water resources for all water uses
- Preserve diversity in the water basin
- Enough platforms to cooperate (water quality issues)
- cooperation for a water-secure and resilient Danube region that ensures water for all
- Source of water services provision
- Source of identity (Danube connects people)
- communication on the Danube network
- Research subject
- Natural system

*Objective*s:

- Increasing requirements for environmental protection
- Cost-effective and competitive IWT on the Danube despite climate change
- Fulfilling requirements EU water framework directive
- Fulfilling requirements of EU flood directive
- Ensure cooperation between states
- Data for water bodies
- SH involvement
- Monitoring
- Providing enough water and of a good quality enough for all water uses
- Drinking water supplies
- Wastewater treatment
- Flood protection

- Keep the Danube basin clean, healthy and safe (water status)
- Sustainable use of water
- Acknowledging all water-related sectors
- Ensure cooperation and collaboration among different stakeholders and different projects.
- Sustainable water resources.
- EU regulations and directives (reduce flood risk)
- Reach good ecological status (water framework directive)
- Reach good conservation status (water framework directive)
- Defining a trans-European network and regulation for navigation
- Building a water-secure Danube region (providing water-related services, irrigation, etc.)
- Sustain the resources
- Ensure resilience against extreme water events
- Embracing sustainable development (ecological, economical, sociological)
- Improving the living conditions of people
- Technical language should not be isolated but put into society building
- More resilient and sustainable region
- Minimalization of flood and drought risk
- Biodiversity (improving)
- Water balance
- Sustainable hydropower and navigation
- Reflecting on conjunctive use and protection
- Sustainable river management
- Sediment balance and river morphology
- River revitalization
- Sustainable hydropower
- Fisheries
- Sediment management
- Hydropicking mitigation
- Monitoring

Benefits:

- Address ties and interdependencies (connectivity between the different countries)
- Ensure efficient waterway
- Ensure fair navigation
- Ensure fairway parameters (2.5 m in 343 d/y).
- River is flowing. Danube connects people
- Danube is good to bring EU regulations into non-EU countries (Balkans)
- People development, society development (the connection between society and EU policy bodies)
- Cultural development and sustainability

Danube Delta

Values:

- Environmental protection
- Irrigation (efficient use, e.g. precision irrigation techniques)
- Climate change adaptation
- New tools for climate change adaptation (stakeholders' cooperation)
- Food affordability
- Good water quality for agriculture

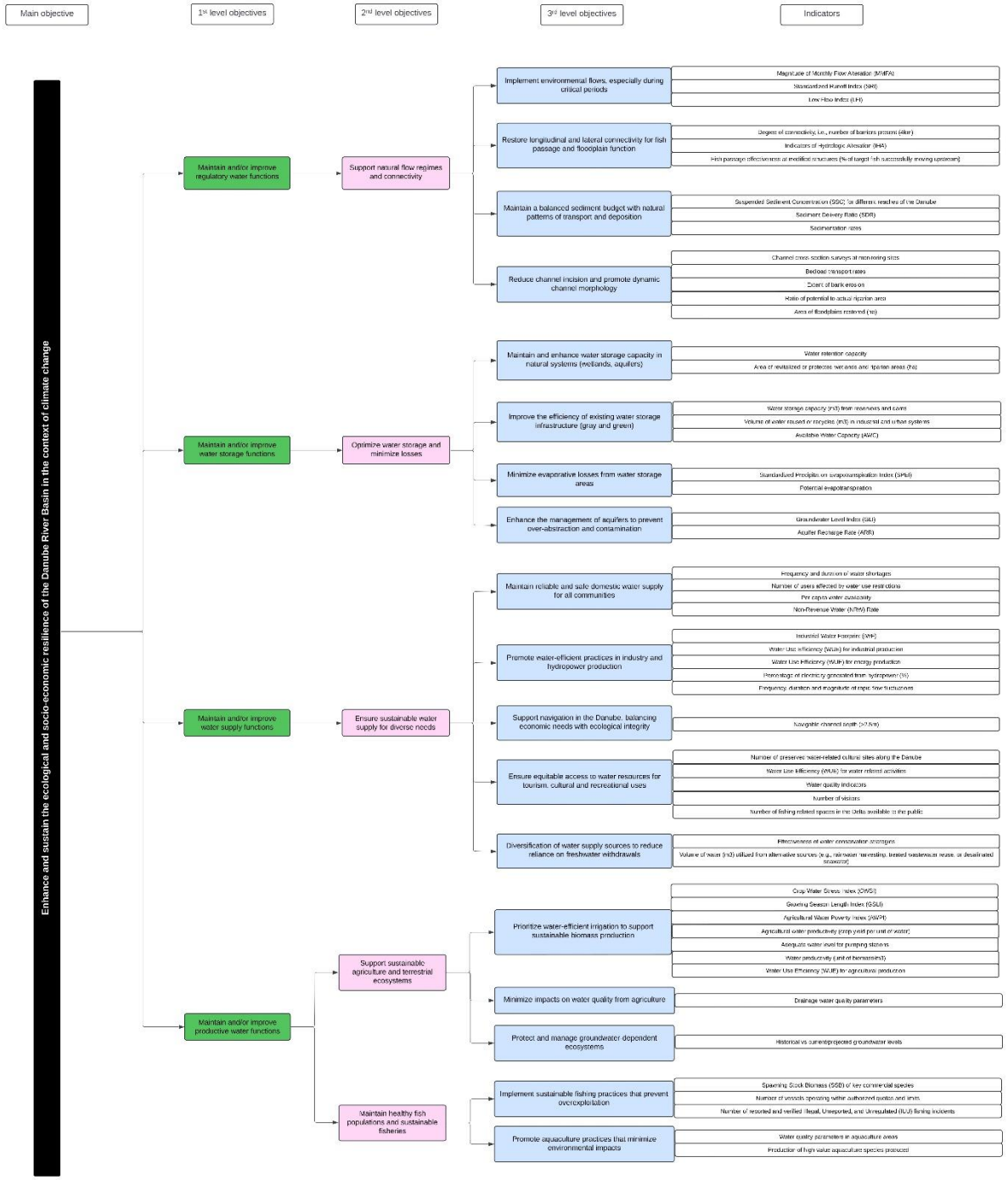
Objectives:

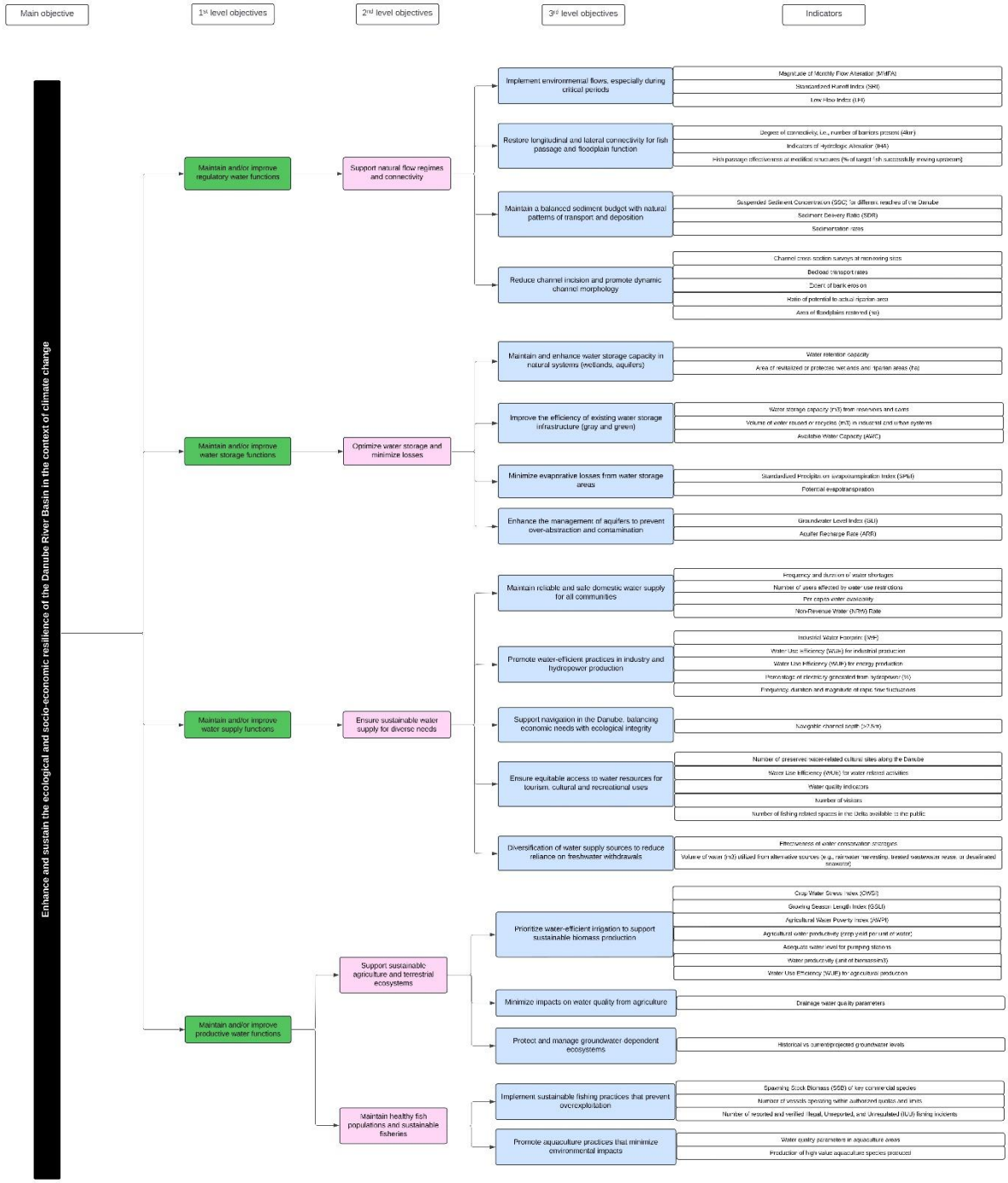
- Good biophysical parameters
- Reconnecting freshwater with marine water (in the Delta, the level of lakes is decreasing, too much sedimentation)
- Safe water level (for pumping stations)

Benefits:

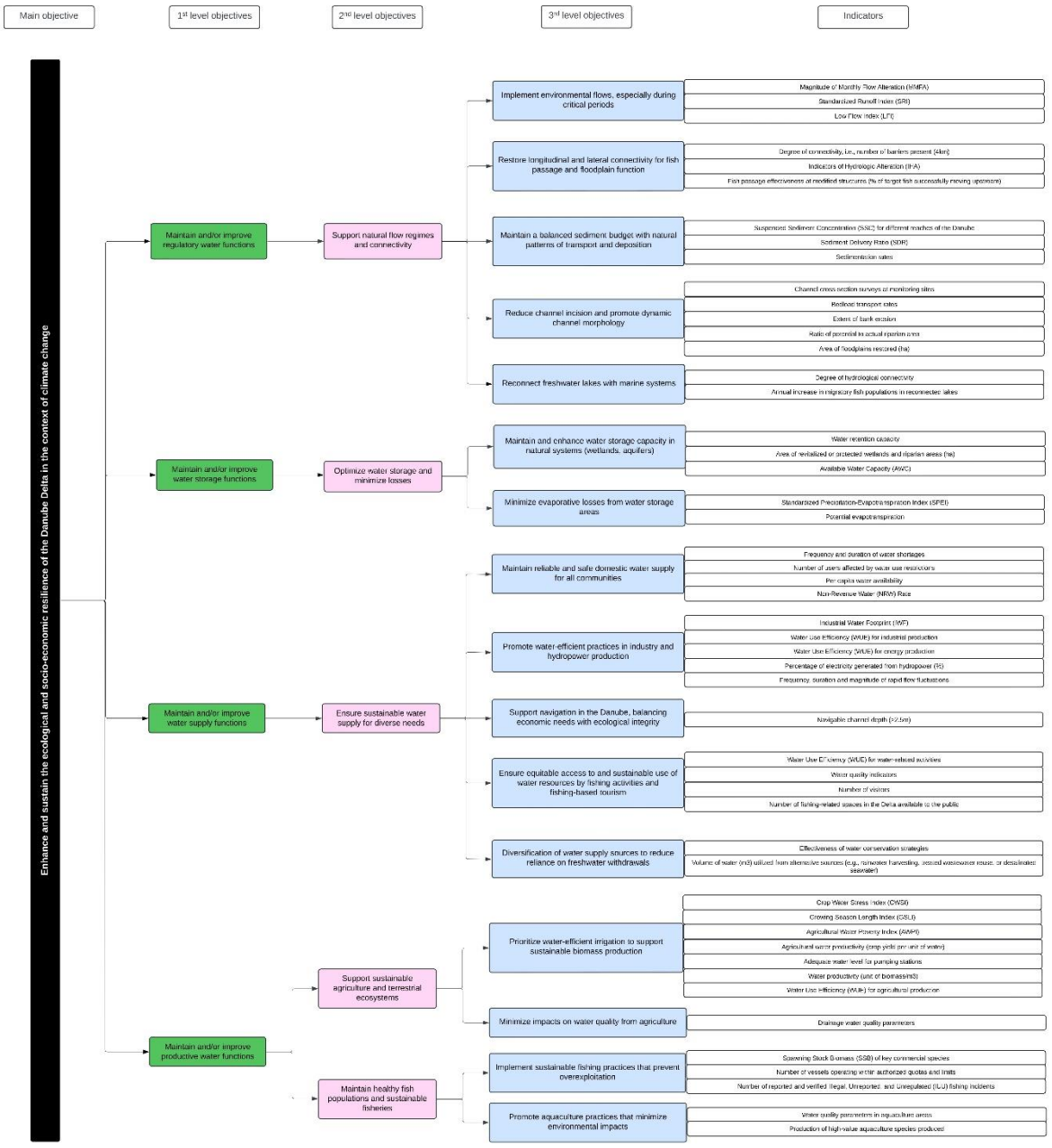
- Maintaining and creating a biosphere reserve
- Water for crop irrigation

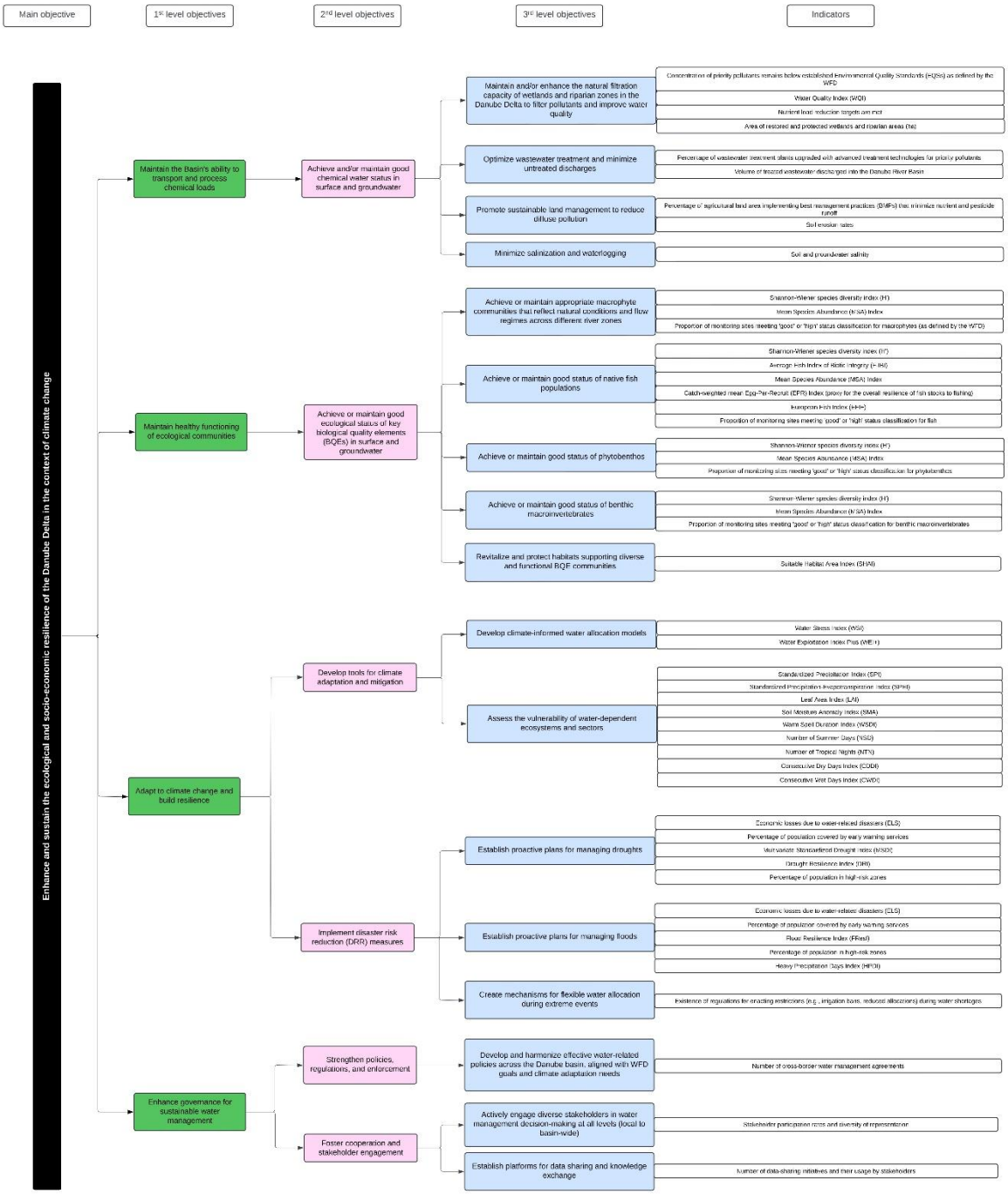
Annex 5: New co-designed objective hierarchy for the entire Danube Basin




Main objective
1st level objectives
2nd level objectives
3rd level objectives
Indicators
Enhance and sustain the ecological and socio-economic resilience of the Danube River Basin in the context of climate change
Maintain and/or improve regulatory water functions
Support natural flow regimes and connectivity
Implement environmental flows, especially during critical periods
Magnitude of Monthly Flow Alteration (MMFA)
Standardized Runoff Index (SRI)
Low-Flow Index (LFI)
Restore longitudinal and lateral connectivity for fish passage and floodplain function
Degree of connectivity, i.e., number of barriers present (Abir)
Indicators of Hydrologic Alteration (IHA)
Fish passage effectiveness at modified structures (% of target fish successfully moving upstream)
Maintain a balanced sediment budget with natural patterns of transport and deposition
Suspended Sediment Concentration (SSC) for different reaches of the Danube
Sediment Delivery Ratio (SDR)
Sedimentation rates
Reduce channel incision and promote dynamic channel morphology
Channel cross-section surveys at monitoring sites
Bedload transport rates
Extent of bank erosion
Ratio of potential to actual riparian area
Area of floodplains restored (ha)
Maintain and/or improve water storage functions
Optimize water storage and minimize losses
Maintain and enhance water storage capacity in natural systems (wetlands, aquifers)
Water retention capacity
Area of revitalized or protected wetlands and riparian areas (ha)
Improve the efficiency of existing water storage infrastructure (gray and green)
Water storage capacity (m3) from reservoirs and dams
Volume of water reused or recycled (m3) in industrial and urban systems
Available Water Capacity (AWC)
Minimize evaporative losses from water storage areas
Standardized Precipitation Evapotranspiration Index (SPEI)
Potential evapotranspiration
Enhance the management of aquifers to prevent over-abstraction and contamination
Groundwater Level Index (GLI)
Aquifer Recharge Rate (ARR)
Maintain and/or improve water supply functions
Ensure sustainable water supply for diverse needs
Maintain reliable and safe domestic water supply for all communities
Frequency and duration of water shortages
Number of users affected by water use restrictions
Per capita water availability
Non-Revenue Water (NRW) Rate
Promote water-efficient practices in industry and hydropower production
Industrial Water Footprint (WFI)
Water Use Efficiency (WUE) for industrial production
Water Use Efficiency (WUE) for energy production
Percentage of electricity generated from hydropower (%)
Frequency, duration and magnitude of rapid flow fluctuations
Support navigation in the Danube, balancing economic needs with ecological integrity
Navigable channel depth (>2.5m)
Ensure equitable access to water resources for tourism, cultural and recreational uses
Number of preserved water-related cultural sites along the Danube
Water Use Efficiency (WUE) for water related activities
Water quality indicators
Number of visitors
Number of fishing related spaces in the Delta available to the public
Diversification of water supply sources to reduce reliance on freshwater withdrawals
Effectiveness of water conservation strategies
Volume of water (m3) utilized from alternative sources (e.g., rainwater harvesting, treated wastewater reuse, or desalinated seawater)
Maintain and/or improve productive water functions
Support sustainable agriculture and terrestrial ecosystems
Prioritize water-efficient irrigation to support sustainable biomass production
Crop Water Stress Index (CWSI)
Growing Season Length Index (GSLI)
Agricultural Water Poverty Index (AWPI)
Agricultural water productivity (crop yield per unit of water)
Adequate water level for pumping stations
Water productivity (unit of biomass/m3)
Water Use Efficiency (WUE) for agricultural production
Minimize impacts on water quality from agriculture
Drainage water quality parameters
Protect and manage groundwater dependent ecosystems
Historical vs current/projected groundwater levels
Maintain healthy fish populations and sustainable fisheries
Implement sustainable fishing practices that prevent overexploitation
Spawning Stock Biomass (SSB) of key commercial species
Number of vessels operating within authorized quotas and limits
Number of reported and verified Illegal, Unreported, and Unregulated (IUU) fishing incidents
Promote aquaculture practices that minimize environmental impacts
Water quality parameters in aquaculture areas
Production of high-value aquaculture species produced

Annex 6: New co-designed objective hierarchy for the Danube Delta




Main objective
1st level objectives
2nd level objectives
3rd level objectives
Indicators
Enhance and sustain the ecological and socio-economic resilience of the Danube Delta in the context of climate change
Maintain the Basin's ability to transport and process chemical loads
Achieve and/or maintain good chemical water status in surface and groundwater
Maintain and/or enhance the natural filtration capacity of wetlands and riparian zones in the Danube Delta to filter pollutants and improve water quality
Concentration of priority pollutants remains below established Environmental Quality Standards (EQSs) as defined by the WFD
Water Quality Index (WQI)
Nutrient load reduction targets are met
Area of restored and protected wetlands and riparian areas (ha)
Optimize wastewater treatment and minimize untreated discharges
Percentage of wastewater treatment plants upgraded with advanced treatment technologies for priority pollutants
Volume of treated wastewater discharged into the Danube River Basin
Promote sustainable land management to reduce diffuse pollution
Percentage of agricultural land area implementing best management practices (BMPs) that minimize nutrient and pesticide runoff
Soil erosion rates
Minimize salinization and waterlogging
Soil and groundwater salinity
Maintain healthy functioning of ecological communities
Achieve or maintain good ecological status of key biological quality elements (BQEs) in surface and groundwater
Achieve or maintain appropriate macrophyte communities that reflect natural conditions and flow regimes across different river zones
Shannon-Wiener species diversity index (H)
Mean Species Abundance (MSA) Index
Proportion of monitoring sites meeting 'good' or 'high' status classification for macrophytes (as defined by the WFD)
Achieve or maintain good status of native fish populations
Shannon-Wiener species diversity index (H')
Average Fish Index of Biotic Integrity (= IBI)
Mean Species Abundance (MSA) Index
Catch-weighted mean Egg-Per-Recruit (EPR) index (proxy for the overall resilience of fish stocks to fishing)
European Fish Index (=FIX)
Proportion of monitoring sites meeting 'good' or 'high' status classification for fish
Achieve or maintain good status of phytobenthos
Shannon-Wiener species diversity index (H')
Mean Species Abundance (MSA) Index
Proportion of monitoring sites meeting 'good' or 'high' status classification for phytobenthos
Achieve or maintain good status of benthic macroinvertebrates
Shannon-Wiener species diversity index (H')
Mean Species Abundance (MSA) Index
Proportion of monitoring sites meeting 'good' or 'high' status classification for benthic macroinvertebrates
Revitalize and protect habitats supporting diverse and functional BQE communities
Suitable Habitat Area Index (SHAI)
Adapt to climate change and build resilience
Develop tools for climate adaptation and mitigation
Develop climate-informed water allocation models
Water Stress Index (WSI)
Water Exploitation Index Plus (WEI+)
Assess the vulnerability of water-dependent ecosystems and sectors
Standardized Precipitation Index (SPI)
Standardized Precipitation-Evapotranspiration Index (SPEI)
Leaf Area Index (LAI)
Soil Moisture Anomaly Index (SMA)
Warm Spell Duration Index (WSDI)
Number of Summer Days (NSD)
Number of Tropical Nights (NTN)
Consecutive Dry Days Index (CDDI)
Consecutive Wet Days Index (CWDI)
Implement disaster risk reduction (DRR) measures
Establish proactive plans for managing droughts
Economic losses due to water-related disasters (DLS)
Percentage of population covered by early warning services
Multivariate Standardized Drought Index (MSDI)
Drought Resilience Index (DRI)
Percentage of population in high-risk zones
Establish proactive plans for managing floods
Economic losses due to water-related disasters (DLS)
Percentage of population covered by early warning services
Flood Resilience Index (FResI)
Percentage of population in high-risk zones
Heavy Precipitation Days Index (HPDI)
Create mechanisms for flexible water allocation during extreme events
Existence of regulations for enacting restrictions (e.g., irrigation bans, reduced allocations) during water shortages
Enhance governance for sustainable water management
Strengthen policies, regulations, and enforcement
Develop and harmonize effective water-related policies across the Danube basin, aligned with WFD goals and climate adaptation needs
Number of cross-border water management agreements
Foster cooperation and stakeholder engagement
Actively engage diverse stakeholders in water management decision-making at all levels (local to basin-wide)
Stakeholder participation rates and diversity of representation
Establish platforms for data sharing and knowledge exchange
Number of data-sharing initiatives and their usage by stakeholders