Organization for Security and Co-operation in Europe

# Toolkit on Data and Information Exchange in Transboundary Basins

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# Data and information exchange in transboundary basins

## An introductory tool to enhance governance and facilitate cooperation

Edited by Diego Jara

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# Foreword

The majority of countries across the OSCE area rely on shared water resources. Transboundary basins, which cross cultural, language, political and administrative boundaries, require not only strong institutional frameworks but also a foundation of trust, built on transparent and timely data and information exchange. Collaboration on data and information-sharing across borders provides a common basis for transboundary water co-operation, maximising the benefits of these shared water resources with positive implications for peace and security.

The sharing of water-related data is a key element in international agreements, setting the ground for riparian states to regularly exchange information on their shared watercourses. The 1997 UN Watercourse Convention recognizes sharing water resources data is vital to river basin cooperation. The relevance of the principle has also been underlined in the Sustainable Development Goals.

The OSCE has a long track record of working on water management, including water diplomacy, transboundary water co-operation and good water governance. OSCE activities contribute to more effective governance of water resources, also by articulating and materializing benefits of transboundary water co-operation for strengthening trust and good neighbourly relations. Access to data and information is often the first building block of long-term, stable and co-operative relations.

This publication offers an introductory tool to support basin stakeholders, across the OSCE area and beyond, in improving data sharing practices. By outlining key principles, practical approaches and case studies, the document aims to strengthen the capacity of institutions and practitioners to foster dialogue and enable more effective decision-making. Enhanced data and information exchange is a strategic instrument for promoting co-operation, reducing risks and advancing co-operative governance over shared water resources.

We hope that this toolkit can serve as a guide and an inspiration to further invest in open, inclusive and evidence-based collaboration in transboundary water management.

Ambassador Bakyt Dzhusupov, Co-ordinator of OSCE Economic and Environmental Activities

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# Acronyms

| | |
|---|---|
| GIS | Geographic Information System |
| IUCN | International Union for Conservation of Nature |
| OSCE | Organization for Security and Co-operation in Europe |
| RBOs | River Basin Organizations |
| SIA | Strategic Impact Assessment |
| UNECE | United Nations Economic Commission for Europe |
| UNWC | UN Watercourses Convention |
| WDNS | Wireless distributed networks of sensors |
| WQE | Water quality evaluation |
| WQM | Water quality monitoring |

# 1 Introduction

Data and information are essential to guide governments, RBOs and international organizations in the effective management and governance of transboundary waters. Exchanging data and information in good faith facilitates cooperation and serves operators, policy makers, diplomats and users across borders to reach informed agreements over shared waters.

An adequate understanding of the conditions, challenges, needs, interests and priorities in transboundary river basins facilitates the development of management plans, agendas, policies, laws and agreements. Such understanding can only be achieved through the regular exchange of data and information between countries that acting in good faith cooperate for the benefit of nature and people.

The purpose of this Toolkit is to highlight the importance of data and information exchange for the effective management of water and provide an overview of current and available mechanisms to understand and measure water conditions as a means to promote cooperation, peace and regional integration.

# 2 Concepts and definitions

This section presents some of the key concepts, approaches and principles used in the processes of exchanging data and information in terms of transboundary waters between States.

| | |
|---|---|
| Cooperation | Joint efforts between riparian countries for the best use and sufficient safeguard of shared waters.<br><br>Such efforts should be based on sovereign equality, territorial integrity, mutual benefit and good faith. |
| Data | Facts and statistics resulting from measuring or monitoring processes. |
| Data collection | Process of collecting facts and statistics to be used to find out about a particular subject. |
| Data management | Overall process by which data is analysed and managed including its compilation, storage, safe-guarding, listing, organization, extraction, retrieval, manipulation, and dissemination. |
| Environmental Impact Assessment (EIA) | Process of evaluating the likely environmental impacts of a proposed project or development, taking into account interrelated socio-economic, cultural and human-health impacts, both beneficial and adverse. |
| Equitable and reasonable utilization | Exercise of the right to use transboundary waters by riparian countries considering specific relevant factors and circumstances including the geographic, hydrographic, hydrological, climatic, ecological and other factors of a natural character, as well as the social and economic needs of the countries concerned. |
| Good faith | Joint efforts by countries should be done to generate useful and actionable inputs for decision-making. |
| Information | Knowledge obtained from investigations, assessments, studies regarding a specific matter. |
| Monitoring | Process of observation, recording, sampling and analysis of water and ecosystems to determine their conditions. |

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| Obligation not to cause significant harm | Duty imposed on every riparian country requiring that their use of water should be undertaken with due care not to cause significant harm to other countries. |
| Protection of ecosystems | Duty of riparian countries to protect and preserve ecosystems in a transboundary river basin. |
| Strategic Impact Assessment (SIA) | Formalized, systematic and comprehensive process of identifying and evaluating the environmental consequences of proposed policies, plans or programmes to ensure that they are fully included and appropriately addressed at the earliest possible stage of decision-making on a par with economic and social considerations. |
| Water pollution | Impairment of water quality to a degree which reduces the usability of the water for ordinary purposes, or which creates a hazard to public health through poisoning or spread of disease. |
| Good water management | Analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a river basin for the conservation of all its resources for the benefit of people and nature. |
| Water planning | An analytical process developed and continuously modified to address the physical, economic, and sociological dimensions of water use |

*For further reference, visit:*

Convention on the Law of the Non-navigational Uses of International Watercourses (UNWC) Articles 5, 7, 8 and 20.

Astorga Jorquera, E., Soto Oyarzún, L., & Iza, A. (Eds.) (2007). *Evaluación de impacto ambiental y diversidad biológica.* UICN.

Aguilar Rojas, G. & Iza, A.O. (2011). *Governance of shared waters: Legal and institutional issues.* IUCN.

# 3 Importance of data and information exchange

The regular exchange of data and information on transboundary waters can be the entry point for broader dialogues, cooperation, agreement development and regional integration. Such exchange has also the potential to ensure institutional coordination between states and promote transparency and trust, providing mutual assurance of joint compliance with existing water agreements and mutual commitments.

The UN Watercourses Convention is one of the legal instruments that guide the exchange of data and information in transboundary waters. This instrument provides that such data and information is exchanged on a regular basis and that is readily available to inform the condition of the watercourse.

Box 1 Key question: What does “readily available data and information” mean?

An answer to this question will depend on the realities of the transboundary river basin and the level of dialogue and cooperation between riparian countries.
Countries would need to define what can be considered as regular exchange for instance, permanently, every month, every six months or every year.
Readily available data and information refers can be considered as the one that a country can easily access, process and share.

***Key message***
It is suggested that countries negotiating agreements can expressly define the regularity in which data and information is to be exchanged as well as the nature of such data that must be readily available in specific cases such as environmental accidents and the development of large water infrastructure.

Source: Prepared by authors

Box 2 Key question: What type of data and information should be exchanged?

The UN Watercourses Convention provides that data and information to be exchanged should in particular be that of hydrological, meteorological, hydrogeological and ecological nature and related to the water quality as well as related forecasts.

***Key message***
It is important that beyond the physical type of data and information expressed in the UN Watercourses Convention, countries could also share socioeconomic facts and statistics to guide actions and policies in benefit of the people living in a transboundary river basin.

Source: Prepared by authors

## 3.1 Benefits of exchanging data and information

Unsustainable human activities and phenomena related to nature including climate change, floods and droughts have the potential to affect freshwater resources and livelihoods. Data and information on the threats posed by unsustainable activities and nature pressures can be essential to prevent, manage and remediate any potential impact and harm.

Countries sharing transboundary waters need to include clear provisions in their policies, laws and agreements to facilitate data and information exchange.

Technology provides a clear advantage for transboundary water cooperation as this is continuously advancing, for example to obtain satellite data and images with field data to facilitating planning, forecasting, emergency response, water supply, irrigation and drainage, environmental management, basin management, aquatic biodiversity, and navigation (Leb, 2020; Lehmann et al., 2014).

Box 3 Key provisions on data and information exchange

- Coordination of all water-data collection and resource monitoring activities
- Standardization of data collection methods and procedure
- Maintenance of up-to-date records of the data received, possibly filed by river basin and aquifer
- Creation of a centralized hydrologic data unit or data bank at the national level or the basin level, to receive and store all data collected;
- Introduce data exchange mechanisms and protocols
- Ensure that data are published periodically, following a standardized methodology and format
- Make data and information available to the users.

Source: Prepared by authors

## 3.2 Types of data and information to be exchanged

This toolkit suggests to observe, adopt and implement mechanisms to measure and monitor the following types of data and information in transboundary waters:

Table 1 Data and information in transboundary waters

| | |
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| **Hydrological** | Includes river flow quantities, water levels of lakes, and quantities stored in reservoirs. |
| **Meteorological** | Composed of temperature, rainfall, solar radiation, wind speed, and relative humidity at regular time intervals, ideally from a few hours to a few days. |
| **Ecological** | Refers to the health of ecosystems, and considers environmental processes, riverine status, minimum flow requirements, critical flow periods and demands, protected areas, and water demands. |
| **Water quantity and quality** | Essential for calibration of hydrological models. |
| **Water pollutants** | Water contamination is pervasive, and can come from different sources: municipal waste, industrial waste, and agri-food production. These pollutants affect the overall quality of water, becoming important factors for human health and safety, and for the resilience of ecosystems. These sources of contaminants need to be controlled and its data to be shared. |
| **Water abstraction** | Abstraction quantity (surface/groundwater), abstraction quality, return flow quality and quantity". |

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| **Climate models** | Information to forecast drought and precipitation events across river basins, bearing in mind multiple variables that can be sourced even outside the watershed, as marine currents, or ocean temperatures. |
| **Groundwater** | Refers to groundwater levels and pressure, quality, aquifer yields and quality, estimate annual groundwater recharge, aquifer thickness, permeability and storage capacity. |

Source: Prepared by authors

## 3.3 Modalities

States exchange data mostly using indirect mechanisms such as:

1. Prior notification (i.e., "treaty provisions for prior consultations, notification, or consent of planned measures related to water");
2. Formal communications (i.e., "provisions for joint management institutions, regular political consultations, consultations as conflict resolution measures and arbitration").

Data and information can be exchanged in a direct and indirect manner. Direct mechanisms are those included expressly in treaties "hard numbers" such as rates of river flow or levels of water quality and indirect mechanisms such as prior notification and formalized communications. Notwithstanding, direct exchange of data and information provisions have been on the rise since the 1970s, representing nearly 40% of current provisions (Gerlak et al., 2011).

## 3.4 Enabling conditions for effective exchange of data and information

Effective exchange of data and information requires certain minimum conditions to be achieved. The pre-existence of dialogue, good relationships, and trust between States is crucial to facilitate exchange. Adequate funding to monitor and study water as well as the technical skills required by authorities and managers in charge of the data and information is key. Moreover, there are other conditions relating to the participation of the public and specific governance indicators that are detailed in the table below.

Table 2 Enabling conditions for effective exchange of data and information

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| **Political will** | Political will refers to the commitment of decision makers to exchange data and information. This political will is more likely to exist among countries sharing "common values and interests" that contribute to collective actions. Political will might facilitate and enable the negotiation and adoption of agreements to share data and information. |
| **Adequate institutional coordination** | Institutions anchor cooperation. Data and information exchange are primarily produced by institutions for decision-making at the national and local levels.<br>In transboundary waters, a variety of institutions might converge. In this sense adequate institutional coordination is required. |
| **Technical capacities** | The management of transboundary waters is by nature complex. Current means to collect data and information require specific knowledge and expertise to use satellite, telemetry, and communication networks. Technology and data management needs specific skills and knowledge. |
| **Financial capacities** | Technological solutions cannot be used and implemented without finance. Costs of transforming data into information for decision-making is expensive and it is important for States to consider the different variables to budget data and information exchange. This includes measurement mechanisms, personnel, capacity building, permanent technical |

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|---|---|
| | institutions, data collection and its organization, specialized software, technological platforms for data and information sharing, mechanisms for governance of shared water resources (participation, transparency, accountability, and access to justice). Depending on the conditions, instruments, "maintenance and calibration, and laboratory testing" add up to costly infrastructure (Mukuyu et al., 2020, p. 4) |
| **Transparency** | The exchange of data and information should be transparent to serve the principle of good faith. Overall, decisions must be adopted counting on reliable data and information, hence transparency on collection mechanisms, handling, process, and analysis is essential. Consequently, data and information exchange mechanisms must be held to the utmost standards of transparency to secure that inputs for decision-making in the use of transboundary water resources. |
| **Accountability** | The authorities and agencies in charge should secure the highest standards on collection mechanisms, handling, process, and analysis. The usual way of accountability is reporting the efforts made and providing for efficiency indicators. In addition, open access to information allow the public to review data and information, resulting in social control over the quality of data and information. Open data can furnish with evidence to the public to supervise the accounts given by authorities regarding transboundary waters. |
| **Public participation** | The involvement of the public is critical to ensure and monitor effective management of transboundary waters. It is important that the public is aware of the conditions of freshwater resources, more importantly when communities use those resources for drinking water. It is also crucial for the public to be informed about the management, monitoring and about the decisions over water that might affect them. |
| **Access to information** | Access to information is intertwined with public participation considering an integrated water management approach, as it sets the knowledge base for discussion and decision-making. Thus, of particular importance are the mechanisms that are in place for stakeholders to take informed part in decision-making, or lesser forms of participation. Access to information in water resources can have different dimensions.<br>First, data and information held by Governments should be available to all people, as a condition for democratic accountability, participation, and access to justice.<br>Second, data and information must be available between State agencies, to avoid double and incompatible elements for decision-making.<br>Third, data and information should be available among States for the best use of water resources, but as well as for protection of human rights and to avoid significative harm (e.g. health and safety, or environmental damage). |

Source: Prepared by authors

## 3.5 Data exchanged in the Central Asia region

This section presents some of the existing initiatives in terms of data and information exchange in the Central Asia region.

Table 3 Central Asia region

| | |
|---|---|
| **Brief description** | The project aims to improve e information provision in water and environmental sectors in Central Asian countries in order to promote transparency, openness and foster public support for sustainable natural resources use.<br>The project is implemented by SIC ICWC in Tashkent, UNECE, Zoi Environment Network, with the active participation of EC IFAS and ICSD and with the financial support of the Swiss Agency for Development and Cooperation (SDC). |
| **Objectives** | 1. Contribute to closer inter-institutional cooperation under the IFAS umbrella with the purpose of fostering the development of a water management decision support system and responsibility for respective data collection and input.<br>2. Rationalize the information services institutional structure in Central Asian water sector.<br>3. Enhance the content and increase access to Central Asia Regional Water Information Base Project (CAREWIB), including strengthening of data collection and information retrieval mechanisms at the regional and national levels.<br>4. Enhance the informational scope and scale of the CAWater-Info Portal including an online platform of modelling tools.<br>5. Produce various information products including digital publications (collection of materials, printing and transmission to partners, publishing on the web portal) and disseminate them among target user groups and other interested parties. |
| **Link** | http://www.cawater-info.net/about_e.htm |

Source: Prepared by authors

Table 4 Regional information system on water and land resources

| | |
|---|---|
| **Brief description** | The regional information system on water and land resources in the Aral Sea Basin was designed to support decision-making processes addressing the water sector. |
| **Objectives** | To serve as common tool for accounting land and water resources in the Aral Sea basin dynamics aiming assessment of diverse aspects of their use and effectiveness. It should facilitate sustainable management and control of water resources use. |
| **Link** | http://www.sic.icwc-aral.uz/information_system_e.htm |

Source: Prepared by authors

Table 5 Central Asia Water & Energy Program

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|---|---|
| **Brief description** | The Central Asia Water and Energy Program (CAWEP) is a partnership between the World Bank, the European Union, Switzerland (through SECO) and the United Kingdom (through DFID) to strengthen the enabling environment to promote energy and water security at regional level and in the beneficiary countries. Structured along three pillars: (1) energy security; (2) energy-water linkages; and (3) water security, the program pursues three components since its inception in 2009: (a) data and diagnostic analyses; (b) institutions, capacity and dialogue; and (c) supporting investments. |
| **Objectives** | CAWEP promotes water and energy security working at the national scale to strengthen national institutional capacities and sector performance, while at the same time keeping the dialogue on regional cooperation on the agenda in order to create an enabling environment for achieving national and regional energy and water security. |
| **Link** | https://www.worldbank.org/en/region/eca/brief/cawep |

Source: Prepared by authors

Table 6 Central Asia Hydrometeorology Modernization Project

| | |
|---|---|
| **Brief description** | There are three components to the project. The first component is strengthening regional coordination and information sharing: This component will ensure that each of the National Hydrometeorological Services (NHMSs) in the region can share, use, exchange and archive common hydromet data and information, and that each agency has a comparable level of expertise in the production of information and delivery of hydromet services. The second component of the project is strengthening of hydromet services in Kyrgyz Republic. The component will help strengthen Kyrgyz hydromet to ensure that it has the infrastructure and capability to sustainably observe, forecast and deliver weather, water and climate services that meet the country's identified economic and societal needs. The third component of the project is strengthening of hydromet services in Republic of Tajikistan. The component will help strengthen Tajik hydromet to ensure that it has the infrastructure and capability to sustainably observe, forecast and deliver weather, water and climate services that meet the country's identified economic and societal needs. |
| **Objectives** | The objective of the Central Asia Hydrometeorology Modernization Project (CAHMP) is to improve the accuracy and timeliness of hydromet services in Central Asia, with a particular focus on Kyrgyz Republic and Republic of Tajikistan. |
| **Link** | https://projects.worldbank.org/en/projects-operations/project-detail/P120788 |

Source: Prepared by authors

# 4 Processes

States negotiating agreements need to define the adequate methodologies and approaches for the management and collection of data and information. This will help to identify the main objectives and goals of such exchange as well as to establish best measuring and monitoring practices.

Data and information are needed to understand the conditions of freshwater resources and ecosystems to guide processes of planning, policy formulation and policy reform as well as for the adoption and implementation of agreements. From data collection to the adoption of a transboundary agreement, various elements need to be considered, mainly the translation of data into concrete actions.

From a governance perspective, some of the main challenges to translate data and information into policy actions include the lack of technical capacities in water institutions, poor coordination across sectors and levels, institutional fragmentation, absence of key stakeholders such as private sector, academia and civil society as well as the lack of transparency and public access to information.

## 4.1 Capacities and coordination

The challenges to data and information exchange can be addressed through the creation or the strengthening of capacities and the promotion of coordination mechanisms. The following table provides some insights on how to improve the capacities and coordination in transboundary water cooperation.

Table 7 Capacities and coordination

| | |
|---|---|
| **Why is it important?** | The process through which data and information is collected, analysed, managed, shared, visualized, and transmitted in transboundary waters is by nature complex and requires coordination of different stakeholders, resources and capacities. |
| **What needs to be monitored and measured?** | Some of the key indicators that need to be monitored and measured in transboundary waters are:<br>• Water availability<br>• Water quality<br>• Geology<br>• Planned actions<br>• Early warning regarding accidents or extreme events<br>• Water use<br>• Pollution sources<br>• Land use<br>• Recharge and discharge zones of transboundary. |
| **Which technologies are needed?** | The use of hydrological computational systems, or hydro-informatics, is an alternative to the traditional exchange of data that has been used between countries. These systems are linked with Earth observation programs that provide better and more precise data. However, a wide variety of new technical skills are needed to adopt these methods. Therefore, there is a need to strengthen the sector's skill base by training, hiring qualified individuals with adequate technical skills, and forming alliances with other expert institutions.<br>Usually, most of the data interchange is generated by national institutions, which flow to various other institutions for collection and processing. This information is then translated into knowledge for decision-making. To adopt appropriate measures, data and information for transboundary water management should be accurate and timely. The lack of coordination can |

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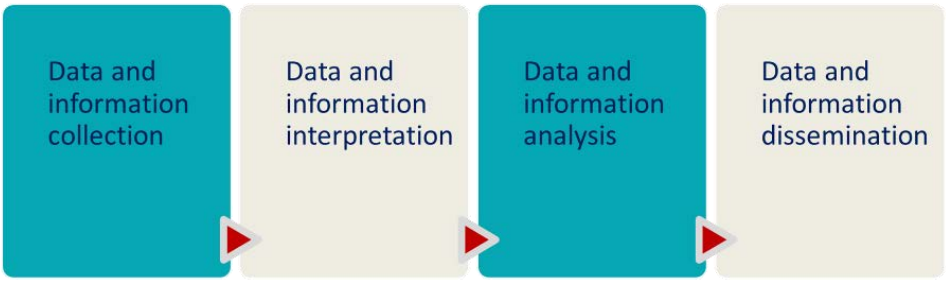
|---|---|
| | lead to misguided details, affecting decision-making outcomes. Therefore, adequate coordination between transboundary institutions is an essential requirement. This coordination should also be integrated, using the same standards and guidelines like monitoring programs, measurement systems and devices, analytical techniques, data processing, and evaluation procedures.<br>In general terms, new technologies are improving data and information exchange. Automated systems enable widespread access and further capacity development. The use of shared data, analytics, and visualization capabilities can help improve agency collaboration. |
| **Benefit** | Sharing data and information contributes to the design of shared goals, and institutionalizing knowledge. |

Source: Prepared by authors

## 4.2 Data and information management

The exchange of data and information in transboundary waters – and more generally its management – can be divided in four main stages.

### Figure 1 Four main stages of data and information exchange




Source: prepared by authors

a. Data collection

The type of data and information on the conditions of transboundary rivers to be collected will depend on the needs, interests, and priorities of riparian counties. The following table presents some of the variables that are generally recommended to be measured and monitored.

Table 8 Data collection process

| | |
|---|---|
| **Type of data and information** | This can be primary data meaning the one collected directly in the field or secondary data based on computer models. |
| **Hydrological (hydrometric)** | River discharges, river water levels, river flood peak discharges, river base flows, river sediment load, river water quality, lake/reservoir water levels, lake/reservoir volumes, lake/reservoir water temperature, lake/reservoir surface evaporation, volume of water imported/exported to/from basin |
| **Hydro morphological alterations** | Dams, weirs |

| | |
|---|---|
| **Future planned measures with transboundary impacts** | Infrastructure development including dams and ports; as well as industrial and mining activities |
| **Groundwater** | Groundwater levels and pressure, water quality, aquifer yields, and quality, estimate annual groundwater recharge, aquifer thickness, permeability, and storage capacity |
| **Meteorological (and climatic)** | Sunshine/radiation hours, wind speed, air temperature, humidity, evaporation and precipitation |
| **Ecological (environmental)** | Minimum flow requirements, critical flow periods and demands, protected areas and water demands, required water quality standards |
| **Water quality** | Electrical conductivity, suspended sediment, nutrients, temperature, pH, oxygen |
| **Water pollutants** | Concentrations of arsenic, bacteria, nitrogen, phosphorus, viruses, fertilizers, pesticides, algae, industrial waste, heavy metals |
| **Water abstraction** | Abstraction quantity (surface/groundwater), abstraction quality, return flow, quality and quantity |

Source: Mukuyu et al. (2020)

Some of the most common monitoring processes are:

Table 9 Common monitoring processes

| | |
|---|---|
| **Conventional water quality monitoring** | Manual collection of samples from various locations in rivers, lakes, and aquifers followed by testing and analysis in a laboratory |
| **Wireless distributed networks of sensors (WDNS)** | With the help of WDNS, measurements may be taken remotely, instantly, and with little assistance from humans. These networks are built on a system of distributed sensors, or nodes, that may send and receive data at distances ranging from a few meters to several kilometers to and from a gateway. |
| **Mobile sensors** | For the exploration of remote areas, the use of sensors in remotely controlled vehicles may be helpful in producing the near-real-time, fine resolution, and spatially explicit data needed for water quality monitoring. New technology includes the use of drones or pollution sensors in swimming robots. |
| **Geospatial technologies** | They utilize and visualize data gathered from terrestrial, aerial, and satellite platforms. They offer spatial-temporal diversity of the quantity and quality of water that is readily available. Combined with on-site data and satellite images, it is possible to assess the colors of the waterbodies and differentiate between variables such as dissolved organic matter, sediments, plankton, and algal blooms. |

Source: prepared by authors

b. Data interpretation

After collection, the following step is to confirm and identify patterns, show changes, and inform policymakers. A recurrent concern in transboundary waters is the assessment and tracking of water availability, allocation, and use with explicitly defined criteria and techniques. The following are some of the systems used for data interpretation: ArcGIS platforms. GIS, or geographic information system, is a technological device that displays layers of data on geographic maps, including remotely sensed data and other recorded data inputs. Urban planners, geologists, hydrologists, environmental scientists, academics, individuals, research institutions, and governments can use them to manage information and data across a range of areas and to present their analysis. Data and information obtained must be presented in a way that can be easily interpreted to guide decisions and identify patterns.

c. Data analysis

After the data has been collected and interpreted, the next step is to analyze the information. The evaluation is a process that depends on various models and analytical tools (Tang et al., 2022). Depending on the situation, the evaluation could entail time-consuming computational procedures. Therefore, international scientific institutions continuously support the creation of increasingly precise evaluation models.

Concerning water quality, the ability to forecast future changes at many parameters enables the development of preventative and regulation methods for water contamination. To forecast the quality of water in water bodies, advanced computing simulations based on Artificial Intelligence (AI) have been successfully applied. Predictions based on AI models provide several advantages over conventional physical and statistical models, including the ability to handle enormous volumes of data and data of various sizes, flexibility, non-linearity, and robustness.

Although specific monitoring networks operate at a transboundary level via a basin or sub-basin configuration, monitoring networks typically function at a national level. Rivers, lakes, and aquifers can only be evaluated simultaneously with meticulous harmonization of data acquired from national systems, particularly related to water quality. Considering the complexity of the analyzing process, cooperative measurements should be based on a joint evaluation to produce more reliable knowledge. In this sense, it is proposed that States create a shared database or information system to exchange data on problems like qualitative and quantitative elements of water and its effects in their transboundary waters.

d. Data dissemination

Two critical aspects of water governance are public participation and access to information, which are established in regional treaties like the Escazu Agreement and the Aarhus Convention. Both agreements recognize the right to a healthy environment; to exercise this right, people must have access to information and be entitled to participate in decision-making.

Public involvement in decision-making improves the quality and effectiveness of decisions, raises public awareness of environmental issues, provides a forum for the public to voice concerns, and enables public authorities to consider such matters.

Public participation and access to information go hand in hand as they provide the background knowledge for discussion and decision-making. The aspects that need to be considered to ensure access to information are as follows:

1. Everyone should have access to the data and information held by governments. This is a requirement for accountability, participation, and access to justice.
2. To prevent using redundant or inaccurate information while making decisions, data and information must be shared among State institutions.
3. Information and data should be available across nations to best use water resources. This also helps in the protection of human rights and in preventing harm. For example, information on the quality of water can promote prevention measures in water use for drinking or irrigation.

The Escazu Agreement and the Aarhus Convention provide the general provisions of the exercise of the right of access to environmental information and the obligations of States to provide the requested information. Additionally, they include the responsibility of States to generate, collect, publicize and disseminate relevant environmental information relevant in a systematic, proactive, timely, regular, accessible, and understandable manner.

In this sense, open access mechanisms should be promoted to enable the public to examine data, resulting in societal control over the information's quality. Open data can provide the public with proof to verify the information provided by authorities on transboundary waters.

## 4.3 The Transboundary Waters Assessment Programme (TWAP)

One of the most comprehensive portals on transboundary water rivers is the TWAP database.

**Box 4 The Transboundary Waters Assessment Programme (TWAP)**

The Transboundary Waters Assessment Programme (TWAP) was initiated by the Global Environment Facility (GEF) to create the first baseline assessment of all the planet's transboundary water resources. This serves a number of purposes, including benchmarking and knowledge exchange, identification and classification of water bodies at risk, and increased awareness of the importance and state of transboundary waters. It is hoped that the TWAP will be of use to a broad variety of stakeholders, including transboundary institutions for specific water systems (e.g. river basin organizations), national institutions and governments, as well as international agencies and donors, to obtain an overview of global issues threatening human populations and ecosystems through the water system. Thus, the long-term goal of the TWAP is to promote investment in management and development of transboundary water systems through strong stakeholder engagement.

The TWAP contains one component for each of the five water systems: (i) Groundwater, (ii) Lake Basins, (iii) River Basins, (iv) Large Marine Ecosystems (LMEs), and (v) Open Ocean. This website hosts the results of the assessment work of the TWAP River Basins component.

The TWAP River Basins (TWAP RB) component is a global assessment of 286 transboundary river basins, aimed at enabling the prioritisation of funds for basins at risk from a variety of issues, covering water quantity, water quality, ecosystems, governance and socio-economics. The TWAP RB assessment also covers risks to deltas from threats of a transboundary nature, and considers the relative influence of lakes on these river basins. TWAP RB is an indicator–based assessment, allowing for an analysis of basins, based on risks to both societies and ecosystems. It also includes provisional outlook projections to 2030 and 2050 for a limited number of indicators.

The methodology of TWAP RB builds on existing datasets and decades of assessment work. Importantly, it involves well-established partnerships between institutions that have a history of working together, as well as bringing in other institutions that add value and expertise and broaden the scope of the network. Formalizing these partnerships under the framework of the TWAP has created a sound basis for a sustainable process.

Source: http://twap-rivers.org/indicators/

# 5 Technologies and scientific innovation

While there are hundreds of tech-driven solutions that are coming to light to address water issues – such as water quality, quantity, use and its connection with climate change processes and international communities –, this section will present some of the most relevant smart techniques, technologies and scientific frameworks that can potentially be co-developed and co-implemented in developing countries to support the exchange of data and information in transboundary waters. The following table presents these potential technologies.

Table 9 Potential technologies and scientific innovation for water diplomacy

| | | |
|---|---|---|
| **1. Monitoring, evaluation and prediction of water quality** | Water quality monitoring | Conventional water quality monitoring processes |
| | | Wireless distributed networks of sensors |
| | | Mobile sensors |
| | | Geospatial technologies |
| | Water quality evaluation | Scientific modelling |
| | Water quality prediction | Artificial Intelligence and big data |
| **2. Water treatment** | Disinfection techniques | Chlorination and solar water disinfection |
| | Electro-chemical techniques | Electro floatation, electro sorption, advanced oxidation processes and anodic oxidation with boron-doped diamond electrodes |
| | Filtration | Membrane filtration, bio sand filtration and ceramic filtration |
| | Nanotechnologies | Nanoparticles, nanocomposites, carbon nanotubes, thin films, quantum dots and new generation polymers |
| **3. Water catchment, storage, supply and pricing** | Water catchment and storage | Scientific modelling |
| | | Conventional and unconventional techniques to capture water |
| | Water supply and pricing | Artificial Intelligence and big data |
| | | Renewables energies |
| **4. Water use** | Smart WASH systems | Toilets based on aerobic bacteria and worms that compost the human waste, novel pit latrine emptying solutions and water-free toilets |

| | | |
|---|---|---|
| | Smart farming | IoT-based terrestrial and aquatic sensors, geospatial technologies and unmanned aerial vehicles (drones) |
| **5. Prevention and adaptation to the effects of climate change** | Prevention | Artificial Intelligence and big data |
| | | Geospatial technologies |
| | Adaptation | |
| **6. Dissemination of water-related knowledge** | | |

Source: Prepared by authors

## 5.1 Water quality

a. Monitoring

Water quality challenges due to anthropogenic and natural pollution can affect the amount of water available for use. Improving water quality monitoring (WQM) involves analysing water properties in freshwater sources such as rivers, streams, lakes ponds, springs, reservoirs, shallow or deep groundwater, cave water, flood plains, wells and wetlands (Daoliang & Shuangyin, 2018). Preserving water quality depends on the accurate monitoring of chemical, physical and biological water parameters such as salinity, Chloride, pH, electrical conductivity, oxidation-reduction potential, dissolved oxygen, turbidity and temperature (Umair et al., 2020). Considering the large number of water parameters that can be monitored, there is a wide-ranging provision of different types of sensors that have been developed over the years to monitor each of these parameters. This section will focus on the types of processes linked to the sensors, and not on the types of sensors themselves. The main WQM processes can be broadly classified as displayed below.

- *Conventional water quality monitoring processes*

They involve manual collection of samples from various points of the water under study, followed by laboratory testing and analysis. These processes have limitations due to the spatial-temporal variability of water parameters, especially when they are used to monitor large bodies of water, such as rivers, lakes, seawater or groundwater. Moreover, they have proved to be ineffective since it is laborious, time consuming and lacks real-time results (Mompoloki et al., 2017). An example of the implementation of conventional WQM processes was part of the observation that took place during a 25-year period (1969 – 1992) in the Lake Kinneret (Sea of Galilee), the largest freshwater body in the Middle East, shared among Israel, Syria and Lebanon (Hambright et al., 2000).

- *Wireless distributed networks of sensors*

Wireless distributed networks of sensors (WDNS) based on Information and Communication Technologies (ICT) and the Internet of Things (IoT) are options to conventional monitoring processes. WDNS allow measurements to be taken remotely, in real-time and with minimal human intervention. These networks are based on a series of distributed sensors (nodes) which are able to send/receive information to/from a gateway (base station) in ranges varying from tens of meters to several kilometres (Geetha et al., 2016). WDNS have experienced a huge upswing with the rising trends of microcontrollers, microelectromechanical systems (MEMS), optical sensors and bio-sensors (Bhardwaj et al., 2015). For instance, prototypes of low cost, continuous WQM based on WDNS have been successfully tested in the Lake Victoria, one of the most important ecosystems in the Eastern African region, shared among Burundi, Kenya, Rwanda, Tanzania and Uganda (Faustine et al., 2014).

- *Mobile sensors*

In recent decades, integrating sensors in remotely controlled vehicles has gained a great deal of interest for the exploration of hard-to-reach locations. In-field data from mobile sensors could be useful to generate of near-real-time, fine resolution and spatially explicit data required for WQM. This trend has led to the emergence of unconventional mobile sensors integrated in unmanned aerial vehicles (drones) (Mbulisi, et al., 2021) such as the one used to carry out a basic water quality assessment in the Luchenza River (Malawi) (Vellemu et al., 2021), or pollution sensors integrated in bio-inspired swimming robots (Bayat et al., 2016).

- *Geospatial technologies*

Geospatial technologies visualize and use information collected from ground, airborne and satellite platforms. They have been widely proven to provide spatial-temporal variability of both quality and quantity of available water. When coupled with in-situ data, satellite imagery aids in WQM by assessing waterbodies colours and distinguishing between parameters such as dissolved organic matter, sediments, plankton, and algal blooms. A recent application of geospatial technologies in the field of WQM has been carried out in Lake Atitlán (Guatemala), using space-borne hyperspectral sensors correlated to on site water samples to resolve for chlorophyll a concentration in the lake (Flores-Anderson et al., 2020).

b. Evaluation

- *Scientific modelling*

All data needed for Water quality evaluation (WQE) can be collected by means of the WQM processes. However, there is no single parameter that defines water quality completely. WQE is a complex process that relies on diverse models such as single/multiple parameters models, comprehensive evaluations, grey correlation analyses, multivariate statistical analyses (Tang et al., 2022) and the aggregation of water quality parameters to calculate indexes. Depending on the case, WQE may involve lengthy computational processes. International efforts of scientific communities are constantly put to the service of developing more accurate WQE models. For further reference see Wuhan section of Yangtze River, China (Tang et al., 2022).

c. Prediction

- *Artificial Intelligence and big data*

Water quality prediction (WQP) involves forecasting variation patterns in the quality at a certain time. Forecasting future changes in water quality at varying parameters allows to devise strategies for the prevention of water contamination and the regulation of water quality. Advanced computing simulations based on Artificial Intelligence (AI) such as support vector machines, diverse kind of artificial neural networks (Al-Adhaileh & Waselallah Alsaade, 2021) and Deep Learning (DL) techniques (Prasad et al., 2022) have been successfully applied to forecast water quality in water bodies. WQP based on AI models have several advantages over traditional physical and statistical models, as they are less sensitive to data insufficiency, the structures are flexible, non-linear, and robust and can handle vast amounts of data and data at different scales. In this context, a successful application of AI has been carried out for early water pollution control in Tyhume River, Bloukrans River and Buffalo River (Eastern Cape Province of South Africa) (Setshedi et al., 2021).

## 5.2 Water treatment

Water public services are normally interrupted during natural disasters, humanitarian crisis and armed conflicts. Also, they are inexistent in underdeveloped geographical zones. In these scenarios, safe water is scarce, and the affected populations try to obtain water from sources such as surface- and ground-water, harvested rainwater, greywater and sewage. In these cases, water is accessible, but is not safe to drink or to use for household or agricultural activities without further treatment. Water treatment occurs in a number of ways, depending on the type of chemical, physical and biological substances that have to be removed, the source of these substances (originated from a point source or a non-point source), and whether the treatment is meant to obtain drinking (higher quality water) or non-drinking water. The main technologies used to improve quality water for drinking and non-drinking purposes are displayed in this chapter.

a. Disinfection techniques

While water disinfection does not involve any technology, disinfection techniques such as chlorination and Solar water disinfection (SODIS) are widely used in developing countries as an inexpensive method to destroy most bacteria and viruses and some protozoa that cause diarrheal diseases. Chlorination requires a sodium hypochlorite solution (chlorine) to be added to the contaminated water. However, when chlorination is used long-term, it is likely to cause increased risk of bladder and rectal cancers (Morris et al., 1992), as well as adverse during pregnancy, such as increased spontaneous abortion rates and foetal anomalies (Bove et al., 2002). Solar water disinfection (SODIS) consists of placing water into transparent plastic or glass containers which are then exposed to the sun, combining the effect of thermal heating of solar light and UV radiation. While SODIS is able to make contaminated water safe to drink by ridding it of infectious disease-causing biological agents, it cannot remove non-biological agents such as toxic chemicals or heavy metals.

b. Electro-chemical techniques

Electrochemical techniques induce the removal of dissolved contaminants in the water by using an electric current passed through the water under treatment by means of suitable electrodes. There is a wide range of techniques ranging from removal of inorganic compounds by electrodialysis, electrocoagulation (Padmaja et al., 2014), and capacitive deionization to removal of organic compounds by electro floatation, electro sorption, advanced oxidation processes, and anodic oxidation with boron-doped diamond electrodes. Novel technologies, such a WATA devices, combine electro-chemical and disinfection techniques to purify water by electrolysis .

c. Filtration techniques

Infiltration is the mechanical or physical operation which is used for the separation of solids from fluids by interposing a medium through which only the fluid can pass (Padmaja et al., 2014). A large variety of filtration techniques and technologies have been traditionally used to treat water. Some of the most popular are membrane filtration, bio sand filtration and ceramic filtration.

d. Nanotechnologies

Nanotechnologies refer to a broad range of technologies that involve particles on the size scale of a few to hundreds of nanometres. Particles of this size have some unique properties due to their capability to create precise structural controlled materials that lend themselves to novel uses. Nanotechnologies applied to water treatment processes are considered to be highly efficient and cost-effective compared to conventional methods. Recently, several natural and engineered nanomaterials such as nanoparticles, nanocomposites, carbon nanotubes, thin films, quantum dots (Padmaja et al., 2014) and new generation polymers, have proven to be excellent adsorbents, catalysts, and sensors with strong water treatment properties. A successful example of CO2 adsorption (Peng, Li, et al., 2018) and heavy metal extraction (Sun, et al., 2018) from water mixtures are the Metal−Organic Framework (MOF)/Polymer Composites.

## 5.3 Water catchment, story and supply

a. Water catchment and storage

Improving the efficiency of water catchment and storage of water needs to be addressed at international, national, community and households' levels, and different techniques, technologies and scientific models are addresses at each level. Some of the main innovative solutions related to the improvement of water catchment and storage are presented below.

- *Scientific modelling*

When water basins are shared at national or international level, – catchment and storage in reservoirs and transportation in major channels – can affect the amount of water that is shared among riparian geographical areas. For instance, the Nile River Basin runs through 11 countries whose combined population totals over 300 million people: Egypt, Ethiopia, Eritrea, Kenya, Rwanda, Burundi, Tanzania, Uganda, Sudan, South Sudan, and the Democratic Republic of the Congo. In Nile River Basin, differences among environmental and anthropogenic factors as well as catchment, storage and transport water management in the upstream and downstream regions cause unceasing debates around the allocation of the 84 billion cubic meters of water that flow on average, every year down the river. Recent scientific investigations have laid the foundations for cutting-edge frameworks addressing 'how much surface water storage can a river basin sustainably accommodate and how should it be distributed in the river network in a way that maximizes gains and minimizes negative ecological and social impacts' (Eriyagama et al., 2020). These studies have revealed evidence-based conclusions about the optimal dimensioning and numbering of large and small reservoirs to maximise the delivery of benefits linked to hydroelectricity, irrigation, residential and industrial water supply, flood protection, fishing and recreation.

- *Conventional and unconventional techniques to capture water*

When water public services are interrupted or inexistent, water catchment and storage need to be carried out at household and community levels. Where groundwater is available, traditional solutions are installing local wells, however, wells are normally big and hard to dig by hand. In low- and middle-income countries (LMIC) in South East Asia, Arica and Latin America , the construction of boreholes based on smart manual drilling techniques such as Baptist and EMAS drilling methods are widely used to reduce costs and efforts. Where groundwater is unavailable, rainwater harvesting can provide a source of alternative water provision by capturing, diverting and storing rainwater from rooftops for treatment and later use (Oweis, 2017). When precipitation levels are low, increasingly creative and unconventional techniques to catch water such as rain enhancement through cloud seeding (Lohmann & Feichter, 2005) and fog harvesting by means of micropatterning of a superhydrophobic surfaces (Zhang et al., 2015) are currently being explored.

b. Water supply

One of the major issues affecting water utilities in LMIC are huge volumes of water being lost through leaks during water transportation, distribution and supply. There are considerable differences between the amount of water put into the distribution system and the amount of water billed to the consumers, the so-called non-revenue water (NRW). High levels of NRW seriously affect the financial viability of water utilities in LMIC, reflecting not only defective water supply techniques and technologies, but also multiple political and economic constraints (Liemberger & Marin, 2006). Identifying new technologies and their costs and benefits, can change the dynamics of supply and demand in a basin, reducing overall costs, rethinking water financing and easing social and political pressures. The main technologies used to improve water supply and pricing are displayed below.

- *Artificial Intelligence and big data*

Smart water supply is based on the combination of cost-effective sensors (acoustic sensors, gas tracers, etc.), calibrated hydraulic scientific modelling of the water supply network, and advanced numerical techniques such as AI and big data. AI or machine learning (ML) algorithms such as artificial neural networks, support vector machines, classification trees and adaptive neuro-fuzzy inference systems can be properly trained with large data sets to detect water leak patterns and faults in the water supply network (Hubert et al., 2020) and forecast water and wastewater network conditions. In addition, AI and big data applied are also optimizing the decision-making processes linked to the financial operations of the water industry, being able to create opportunities for responsible investment (Neelke, 2021), reducing water pricing for consumers.

- *Renewables energies*

The growth of the world's capacity to generate electricity from natural resources such as water, wind and sun is on course to accelerate over the coming years, supporting the emergence of the new global energy economy. Investigating the potential and the potential combination of novel complementary renewable energy technologies, such as water and wind turbines and solar panels, may arrive at balancing power solutions that meet expected consumption profiles and pricing, while benefiting social, political and environmental demands. For instance, the development of large-scale hydropower is proceeding rapidly in Mekong River Basin, which flows through China, Myanmar, Thailand, Lao PDR, Cambodia and Vietnam. Combining complementary renewable energy sources may have the potential of diminishing the severe and cumulative negative impacts that dams and reservoirs have on biodiversity, livelihoods and the economies of the lower Mekong countries (Campbell & Barlow, 2020).

## 5.4 Water use

Changing water use practices is particularly important at the level of households and communities, and requires individuals to reflect on the management of water for domestic purposes as well as for agriculture, and how they prioritize, value, and pay for the water they use. Some examples of how to improve water use at household and community levels are displayed below.

a. Smart WASH systems

The lack of appropriate water and sanitation hygiene systems (WASH) has negative impacts on health and mortality, the environment, and ultimately, on economic growth. While flush toilets and central sewer systems are considered to be the gold standard for safe sanitation, decentralized sanitation systems that incorporate reengineered toilets that do not require connections to water supply or sewers can be more resilient, cost-effective, and environmentally friendly. Some reinvented toilet models provide sanitation for single homes, while others are designed for public or shared toilet facilities that serve communities. New designs based on aerobic bacteria and worms that compost the human waste (Mema & Gyampo, 2011), novel pit latrine emptying solutions (Jha, 2003) and water-free toilets (Biblob et al., 2011) have been already tested in countries such as India and Bangladesh, setting some of the precedents to set up smart WASH systems in areas that are hard to reach with traditional infrastructure.

b. Smart farming

In LMIC, the vast majority of farmers are smallholder farmers who grow food on a small plot, first and foremost to feed their families. Smallholder farmers often make production activity decisions on the basis of traditional recommendations rather than scientific data. However, the recent proliferation ICT and cell phones in LMIC has enormously shifted how people interact with information; with the development of remote sensing technology, the data linked to food production is growing exponentially across the world. In recent years, numerous smart farming solutions based on IoT-based terrestrial and aquatic sensors, geospatial technologies and unmanned aerial vehicles (drones) are being developed and practiced (Raj Kumar, et al., 2021). The combination of these cutting-edge technologies generates a large volume of geo-spatial data from diversifying sources that can be collected and analysed by means of AI and big data to automate farming processes and provide rapid data analysis to identify and improve soil quality, reduce the waste of water during irrigation and share agricultural information with farmers.

## 5.5 Climate change

a. Prevention

According to the Intergovernmental Panel on Climate Change (IPCC, 2008), 'the relationship between climate change mitigation measures and water is a reciprocal one'. While reducing greenhouse gas (GHG) emissions has direct implications for protecting water resources, sustainable water management has a key impact on carbon emissions due to the emissions generated during water processes. However, increasing variability in water cycles is contributing to extreme weather events, reducing the predictability of water availability. The main tech-driven water solutions linked to climate change prevention involve the acquisition and interpretation of key observational data.

- *Artificial Intelligence and big data*

By developing effective AI-based and big data models for the monitoring, evaluation, and prediction of hydrologic processes and weather forecasting, better-informed decision-making processes to mitigate the impacts of natural disasters and climate change can be put in place. Tech-driven ability to anticipate when floods and droughts will occur has been improved by means of ML-based models to predict floods (Li-Chiu, et al., 2019), artificial neural networks to forecast streamflow (Jianzhong, et al., 2018) and droughts (Oluwatobi, et al., 2017).

- *Geospatial technologies*

They have proved to be an important tool to examine the changes and to suggest adaptation and mitigation, locally, regionally and globally. Collecting large amounts of data on environmental changes and geographical and anthropogenic processes by means of remote sensors along with inter-operability through the latest computing and software techniques helps infer the nature and characteristics of climate change in all continents and oceans (Janardhanan, et al., 2014). One example of the satellite monitoring and evaluation of hydrologic processes are the ongoing investigations that are studying the glacial lake outburst flood phenomena in Patagonia (Anacona, et al., 2015).

b. Adaptation

According to the United Nations Framework Convention on Climate (UNFCC), the use of technology for climate change adaptation has been broadly defined as “the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change”. When it regards to water technologies and techniques that address challenges resulting from climate change and help to build adaptive capacity, there is a long list of innovative solutions that, in one way or another, contribute to improve human resilience against water fluctuations. Some of the most promising refer to better quality monitoring, evaluation and prediction to limit pollution levels; novel water treatment to counteract salinization; and alternative water catchment and storage (Bertule, et al., 2018).

## 5.6 Dissemination of water knowledge

Transboundary cooperation is needed to address climate impacts that cross national boundaries and avoid maladaptive consequences from a basin perspective. While the dissemination of water-related knowledge would reduce uncertainty, enable costs and benefits sharing, and ease the promotion of peace and stability, often transboundary data sharing remains a challenge in hydrology from both the technological and policy perspective. More effective ways of creating actionable knowledge that is trustworthy, is easily communicated, and will be used by all sides to enhance policy and program implementation are needed. However, simply creating more scientific knowledge, connecting experts, and sharing data is not enough to improve water management. Technology can support the process of enabling multi-sectoral actors to trust in the process of collecting data and creating knowledge, getting coordination; and improving transparency and accountability. Thanks to the increasing spread of ICT, digital platforms and digital clouds can be used as trusted repositories for the data coming from the monitoring, evaluation and prediction of hydrologic and environmental processes that riparian states are carrying out.

## 5.7 Basic principles of monitoring and assessment in a transboundary context

The UNECE Water Secretariat in its "2023 Updated Strategies for Monitoring and Assessment of Transboundary Rivers Lakes and Groundwaters" provides key principles to monitoring that are important to consider in this toolkit:

Table 10 Basic principles of monitoring and assessment

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|---|---|
| **Monitoring and assessment** | The ultimate goal of monitoring is to provide the information necessary for planning, decision-making and operational water management at the local, national and transboundary levels. Monitoring programs are also fundamental to the protection of human health and the environment in general. Assessment is a crucial part of monitoring because it translates the acquired data into information about the current state of a water body. It provides the basis for describing changes and trends which can be linked to pressures and impacts and then related to environmental targets or objectives. |
| **Basin approach** | The basin forms a natural unit for integrated water resources management in which rivers, lakes and groundwaters interact with other ecosystems. A basin refers to either the area of land from which all surface runoff flows through a sequence of streams, rivers, groundwater bodies and possibly lakes into the sea at a single river mouth, estuary, lagoon or delta, or the area of land from which all surface runoff ends up in another final recipient of water, such as a lake or a desert. The whole basin should therefore be considered when developing a monitoring system. |
| **Different purposes** | Information based on well-organized monitoring programs that account for the complexity of issues is a prerequisite for accurate assessments of the status of water resources and the magnitude of water problems. Furthermore, such assessments are essential for preparing proper policy actions at the local, national and transboundary levels. At the transboundary level there is a need for a common basis for decision-making, which requires harmonized and comparable data and information. Indeed, water resources management in transboundary basins requires sharing data and information that meets the expectations of stakeholders for various activities. |
| **Benefit of joint monitoring** | Joint monitoring includes substantial benefits for countries. During the second reporting exercise under the Water Convention in 2020, countries were asked to report on the main achievements they experienced in relation to joint monitoring. A range of benefits and achievements was mentioned including:<br>• mutual support in establishing a monitoring system, developing a joint approach to the future proposal of measures, optimization of activities, joint capacity building, implementing a shared database and drafting joint studies;<br>• agreement on and approving of monitoring parameters and methods, and harmonization of results from chemical, ecological and biological analysis of water from agreed monitoring stations; • improved basin-wide, transparent, harmonized, "neutral" and reliable information, and data on the state of the environment leading to greater technical and scientific understanding of the entire basin as the basis for better management of water bodies; • improved forecasting, impact assessment and dissemination of results for better decision-making; • the development of regular reports such as impact studies and state of the basin reports; • improved early warning through the availability of continuous monitoring results to detect contaminations in time for intervention, as well as for flood forecasting and disaster risk management, including successful coordination and cooperation during flooding events; • improved understanding of the distribution of a basin's water resources and water balance, |

| | |
|---|---|
| | enabling the setting of environmental flows, better control and operational rules for the basin and sub-basins, and efficient water supply to parties involved; • shared concepts of pressures and impacts providing a common ground for cooperation, offering a platform for dispute settlement and improved trust and confidence among riparian states, their institutions, citizens and Indigenous peoples, as well as enhanced cooperation. |

Source: UNECE Water Secretariat, Updated Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters

# 6 Case studies

This section highlights transboundary river basins where riparian countries have adopted agreements contemplating specific provisions on the regular exchange of data and information, as mechanisms and tools for data collection, interpretation, analysis and dissemination.

## 6.1 Sava

Table 11 Sava River Basin

| | |
|---|---|
| **Agreement** | 2002 Framework Agreement on the Sava River Basin |
| **Provisions** | Article 4<br>Exchange of Data and Information<br>Parties shall, on a regular basis, exchange information on the water regime of the Sava River Basin, the regime of navigation, legislation, organizational structures, and administrative and technical practices. |
| **Institutional Framework** | The Sava Commission shall coordinate the establishment of a unified information system.<br>The Statute of the International Sava River Basin Commission provides that a river information system should be instated by the Commission for navigational purposes. |
| **Mechanisms adopted** | As a means to implement the provisions on exchange of quality-controlled data and information contemplated in the Framework Agreement on the Sava River Basin, riparian states promoted the following actions:<br>• 2009 Sava GIS Strategy established vision, principles and objectives for development of Geographical Information System of the Sava River Basin – Sava GIS<br>• 2010 Preparation of the Implementing Documents for Establishment of Sava GIS which provided further conceptualisation and proposal of Sava GIS architecture<br>• 2016 Establishment of a functional Geoinformation System – Sava GIS and the modules for river basin and flood management related datasets, with the support of European Commission<br>• 2018 Improvements of the flood management module and a full compliance with the EU Floods Directive Reporting Guidance 2018, with support of the WBIF and World Bank<br>• 2019 Policy on the exchange and use of Sava GIS data and information<br>• 2021 Improvements of the flood management module and integration of the datasets on cultural-historic heritage endangered by floods, with support of the EU H2020 project (Shelter) |
| **Further information** | International Sava River Basin Commission<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

## 6.2 Dniester

### Table 12 Dniester River Basin

| | |
|---|---|
| **Agreement** | 2012 Treaty between the Government of the Republic of Moldova and the Cabinet of Ministers of Ukraine on Cooperation in the Field of Protection and Sustainable Development of the Dniester River Basin |
| **Provisions** | The Treaty addresses issues relating to the Dniester River basin, with the exception for navigation and hydropower, and is its objective is to strengthen the cooperation between Ukraine and the Republic of Moldova.<br>Furthermore, the Treaty complies with obligation undertaken by both countries under the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992) and the EU Water Framework Directive (2000).<br>The Treaty establishes the Parties shall cooperate, inter alia, in the development and implementation of monitoring programs and the creation of joint information systems- |
| **Institutional Framework** | The Commission on Sustainable Use and Protection of the Dniester River Basin (the Dniester Commission) was established under the Treaty between the Government of the Republic of Moldova and the Cabinet of Ministers of Ukraine on Cooperation in the Field of Protection and Sustainable Development of the Dniester River Basin (Moldovan, Ukrainian), adopted in Rome on 29 November 2012.<br>The Dniester Commission is a body for intergovernmental cooperation in the areas of protection, sustainable use and development. It is structured around working groups including:<br>• Strategic Working Group (core group)<br>• Working Group on Ecosystem and Biodiversity<br>• Working Group on River Basin Planning and Management<br>• Working Group on Emergencies<br>• Working Group on Monitoring and Information Exchange.<br>The Working Group on Monitoring and Information Exchange was established by the Commission on Sustainable Use and Protection of the Dniester River Basin, with the objective of facilitating the organization of current and live information exchange regarding the condition of water and other natural resources and ecosystems of the Dniester River basin, by using common information systems and preparing reports on the status of the basin, which are available to the public. |
| **Mechanisms adopted** | In 2021, Moldova and Ukraine signed a Joint Statement on the Strategic Action Programme for the basin Dniester River Basin for 2021 – 2035. |
| **Further information** | Dniester Commission<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

## 6.3 Aral Sea

### Table 13 Aral Sea

| | |
|---|---|
| **Agreement** | 1992 Agreement between the Republic of Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan and the Republic of Uzbekistan on Cooperation in the Field of Joint Management on Utilization and Protection of Water Resources from Interstate Sources |
| **Provisions** | According to the Agreement the Parties will facilitate wide information exchange on scientific and technological advances in the field of water management, integrated use and protection of |

| | |
|---|---|
| | water resources [as well as promote] joint research to provide scientific and technological inputs and expert appraisals of project plans of water management facilities and economic assets. |
| **Institutional Framework** | The Interstate Commission for Water Coordination (ICWC) |
| **Mechanisms adopted** | The ICWC established in 1992 the Scientific-Information Centre (or SIC-ICWC) as an information and analytical body, with the objective of developing methods and approaches of prospective development, improvement of water management and ecological situation in the basin.<br>The Scientific-Information Centre collaborates with scientific organizations of Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, and Kazakhstan, by organizing scientific and information exchanges at national and regional level. |
| **Further information** | The Scientific-Information Centre<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

## 6.4 Mekong

Table 14 Mekong River Basin

| | |
|---|---|
| **Agreement** | 1995 Mekong River Agreement |
| **Provisions** | Contracting parties collect data and exchange it with the Commission. The MRC consolidates data, produces reports, and derive recommendations (Mekong River Commission, 2022). The basin has an extended network of monitoring stations (automated telemetry hydro-meteorological, rainfall and water level, water quality sampling, ecology health sampling sites, and fisheries monitoring sites). Data is shared with China (Dialogue Partner).<br>The Mekong River Agreement creates a Joint Committee, which is composed by one member from each participating riparian State (Article 21) .<br>Article 24 of the Agreement establishes among the functions of the Joint Committee, to regularly obtain, update and exchange information and data necessary to implement the Agreement, and to maintain databases and all necessary information. |
| **Institutional Framework** | The Mekong River Commission |
| **Mechanisms adopted** | The Procedures for Data and Information Exchange and Sharing (PDIES) regulates the data and information exchange processes, which include information on the following: Water Resources; Topography; Natural Resources; Agriculture; Navigation and Transport; Flood Management and Mitigation; Infrastructure; Urbanization/Industrialization; Environment/Ecology; Administrative boundaries; Socio-economy; and Tourism. Other regulations are: (a) procedures for water use monitoring (PWUM), (b) Procedures for Notification, Prior Consultation and Agreement (PNPCA), and (c) Procedures for Water Quality (PWQ).<br>The Commission has developed a regional information system (MRC-IS), which conveys information produced to all parties, stakeholders, and public at large, through a data Portal (MRC Data and Information Service Portal). The information provided refers, for example, to "current and historical hydro-meteorological and climate time-series, spatial maps, atlases, photographs, and sectorial datasets that can be easily searched and filtered" (Mekong River Commission, 2022). |
| **Further information** | MRC Data and Information Services<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

## 6.5 Rhine

### Table 15 Rhine River Basin

| | |
|---|---|
| **Agreement** | 1999 Convention on the Protection of the Rhine |
| **Provisions** | The Convention contemplates that Germany, France, Luxembourg, Netherlands and Switzerland, together with the European Union shall cooperate and provide mutual information on the Rhine ecosystems within their territories. |
| **Institutional Framework** | This Rhine River basin is managing by the International Commission for the Protection of the Rhine (ICPR). |
| **Mechanisms adopted** | Protocols have been adopted for water quality data (temperature, oxygen, pH, electric conductivity, filtered substances), chemical components, eutrophication substances), inorganic substances, heavy metals, volatile hydrocarbons, Polychlorinated biphenyls, pesticides, Brominated compounds, among many other elements (Parameter list of the Rhine Monitoring Programme – Chemical Component 2015–2020).<br>The Parties have also adopted the Rhine 2020 Programme setting "measurable targets for areas of ecology, floods, water quality, and groundwater protection" (International Network of Basin Organizations & Global Water Partnership, 2012).<br>In order to facilitate transboundary management in the Rhine River basin, the International Commission for the Protection of the Rhine develops, manages and uses different types of Water Information Systems (WIS) that are essential tools for the cross-border exchange and compilation of data within the Rhine river basin.<br>The ICPR members collect and produce complex data related to water quality and quantity issues, and the various stages of this work between the countries within the Rhine River basin are supported on Information Systems on the following areas: i) Rhine Warning and Alarm Plan; ii) Transboundary Information systems related to flood risk management; and iii) Flood forecasting and flood announcement Instrument for assessing the impact of flood risk management measures on risk evolution.<br>For the purpose of enhancing data management related to the implementation of both the European Water Framework Directive and the Floods Directive within the Rhine basin, the ICPR has incorporated, in cooperation with the German Federal Institute of Hydrology (BfG), the use of the water portal "WasserBLIcK", which supports data exchange and the production of different maps for the general and specialized public. |
| **Further information** | International Commission for the Protection of the Rhine<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

## 6.6 Danube

### Table 16 Danube River Basin

| | |
|---|---|
| **Agreement** | 1994 Convention on Cooperation for the Protection and Sustainable use of the Danube River |
| **Provisions** | According to the Convention, Contracting Parties are required to adopt monitoring programmes (Art. 9); reporting (Art. 10); consultations (Art. 11); exchange of information (Art. 12); protection of information supplied (Art. 13); information to the public (Art. 14); research and development (Art. 15); communication, warning and alarm systems, and emergency plans (Art. 16). |
| **Institutional Framework** | In 1998, the International Commission for the Protection of the Danube River (or ICPDR) was established, as a transnational body with the objective of implementing the Danube River Convention. |

| | |
|---|---|
| | The International Commission for the Protection of the Danube River was empowered by the Danube countries to organize data collection and to process information in order to promote decision-making processes. |
| **Mechanisms adopted** | The ICPDR established the Danube River Basin Geographic Information System (Danube GIS), a tool for integration and storage of the relevant data resources, and a common basis for data usage in the ICPDR.<br>Additionally, the ICDPR supported the creation of the Water Quality Database of the Transnational Monitoring Network (or TNMN), with the objective of providing a structured and well-balanced overall view of pollution and long-term trends in water quality and pollution loads in the major rivers in the Danube River Basin.<br>The TNMN monitoring network operates on national surface water monitoring networks and includes 79 monitoring locations with up to three sampling points across the Danube and its main tributaries river. |
| **Further information** | International Commission for the Protection of the Danube River<br>Iza, Alejandro. *International water governance: conservation of freshwater ecosystems*. Vol. 1: International agreements, compilation and analysis (2004) |

Source: Prepared by authors

# 7 Main recommendations

This section compiles a list of recommendations and good practices for data and information exchange to ensure effective transboundary water management.

a. Human, financial and technical capacities

*i.* *Enabling innovation through projects, programs and partnerships, in particular, building on the case of new technologies, practices and approaches*

*ii.* *Allocate specific financial resources on water data and information management*

- to develop and manage information and data systems
- to improve data exchange
- to organize data dissemination
- to support data collection, interpretation, and analysis processes.

iii. *Reinforce human resources and technical capacities on data information collection, interpretation, analysis, and dissemination with specific capacity building programs on water data and information management.*

*iv.* *Introduce reference to water data and information management and exchange in all documents related to transboundary water management*

*v.* *Reinforce national information systems: there is a need for more comprehensive and transparent data collection with storage in a digital format.*

- reinforce national capacities in data management
- develop capacities to exchange data
- using common language and procedures
- support technological solutions to optimize processes towards sustainable use of water resources, applying a water footprint analysis to support governments in formulating policies that are beneficial from an economic and water management perspective
- compiling country data to report on progress towards SDG 6 for stronger accountability and more effective decision-making
- facilitating access to shared, reliable evidence in the domain of water diplomacy considering climate change.

b. Partnerships and external cooperation

*i.* *Promote cooperation and collaboration among riparian countries and facilitate dialogue for joint management of shared water resources.*

- Engaging national capacities in the collection and reporting of water-related data
- Building on existing international initiatives:
  - UN Global Environment Monitoring System (GEMS)
  - Information System on Water and Agriculture of the United Nations Food and Agriculture Organization (FAO AQUASTAT)
  - SDG 6 Data Portal Open-access portal
  - World Meteorological Organization's Hydrological Information Referral Service (WMO INFOHYDRO)

- World Water Quality Assessment
- World Water Data Initiative

- Building on existing partnerships to nurture the exchange of knowledge and good practices: shared monitoring and data exchange support transparent and evidence-based decision-making
- Establish national and regional working groups with water policy experts on the application of the water footprint methodology. The working group would work on:
  - reviewing available data and statistics
  - setting up measures for the exchange of information and joint reporting
  - supporting international partners and consultants.

c. Monitoring and evaluation

*i.* *Strengthen monitoring, evaluation, and prediction of water quality and promote the use of innovative monitoring technologies:*

- Conventional water monitoring processes
- Wireless distributed network sensors
- Mobile sensors
- Geospatial technologies
- Scientific modelling
- Artificial Intelligence and big data
- Applying water footprint assessments to monitor the changes in water footprint and economic value.

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