Convention on the Protection and Use of Transboundary Watercourses and International Lakes

Working Group on Monitoring and Assessment
Fifteenth meeting
Geneva, 6 December 2019

Items 5, 8 and 9 of the provisional agenda
5. Gathering feedback on the guidelines on monitoring and assessment of transboundary waters developed under the Convention
8. Cooperation with partners.
9. Strategic discussion about future work on monitoring and assessment

Outlook for developing monitoring cooperation and exchange of data and information across borders:

Background paper to the Global workshop on exchange of data and information and to the fifteenth meeting of the Working Group on Monitoring and Assessment under the Water Convention (Geneva, 4–6 December 2019)

Note by the secretariat[1] with contributions from the International Network of Basin Organizations, the International Water Management Institute and the World Meteorological Organization

Background

The Programme of Work (PoW) 2019-2021 under the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) includes organization of a global workshop on data and information exchange in order to review relevant experiences, discuss good practices and develop recommendations on the exchange of information on transboundary basins and aquifers, taking into account, among others, new information technologies. The discussions at the workshop, organized in Geneva from 4 to 5 December 2019, were to be supported by a substantive background paper.

The scope of the present paper is as follows: Firstly, it describes the status of exchange of data, what data is actually exchanged and what has been reported as related challenges. Secondly, the strategic approach to monitoring and assessment developed under the Water Convention is presented, which can be applied in developing related cooperation in diverse contexts. Selected technical guidance and standards, notably related to hydrology, and quality management considerations are then referred to, which are helpful for harmonizing data, facilitating exchange. A brief listing of relevant developments in technology and data access draws attention to opportunities that are shaping data acquisition for monitoring and assessment. In the final part, good procedures for data management and data exchange are described, illustrated with some examples. The paper serves to inform reflection about needs and options for future work that could be undertaken under the Water Convention, in cooperation with partners.

[1] The document has been developed and coordinated by Jos Timmerman (WaterFrames) as contribution of the Ministry of Infrastructure and Water Management of The Netherlands.

I. Introduction

A. Objectives

The background document is intended to

1) provide information about existing strategic and technical guidance on monitoring and assessment (including the guidance developed under the Water Convention) and on exchange of data and information; recent technological developments in monitoring and data acquisition across borders (e.g. remote sensing, open data), and how they are helpful for informing transboundary cooperation; and
2) inform reflection about needs for guidance, strategic or technical, and what opportunities this provides for the workshop's organizing partners, the Water Convention secretariat and other interested organizations to assist countries in developing monitoring cooperation and data and information exchange[2]

B. Need for Monitoring & Assessment, and regular exchange of information

Water is a resource without border and at either transboundary or national level, the development of effective water resource management is fundamental to ensure sustainable socio-economic development and health of ecosystems.

An integrated approach in water management that holistically takes into account all the sources of water as well as uses and functions of water resources is necessary. Furthermore, considering Issues such as land-use, navigation, agriculture, industry, urbanization and ecosystems increases the complexity of water management. Water problems are becoming more complex and diverse and require more specific knowledge and integration across various disciplines and sectors.

Experience shows that efficient water resource management cannot exist without efficient access and management of the necessary data and information: easy access and efficient use of the necessary data and information, e.g. on the status and evolution of water resources and uses, is one of the keys to successful water policy implementation.

Information based on well-organized monitoring programmes that cover the complexity of issues is a prerequisite for accurate assessments of the status of water resources and the magnitude of water problems. 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 assessment methods and data management systems as well as uniform reporting procedures to ensure comparable information. Indeed, water resources management in transboundary basins requires sharing data and information that meets the expectations of stakeholders for various activities. Figure 1 outlines some of the main domains requiring access to water-related data:

[2] The fifteenth meeting of the Working Group will discuss possible updating or complementing the guidelines on monitoring and assessment of transboundary waters developed under the Convention

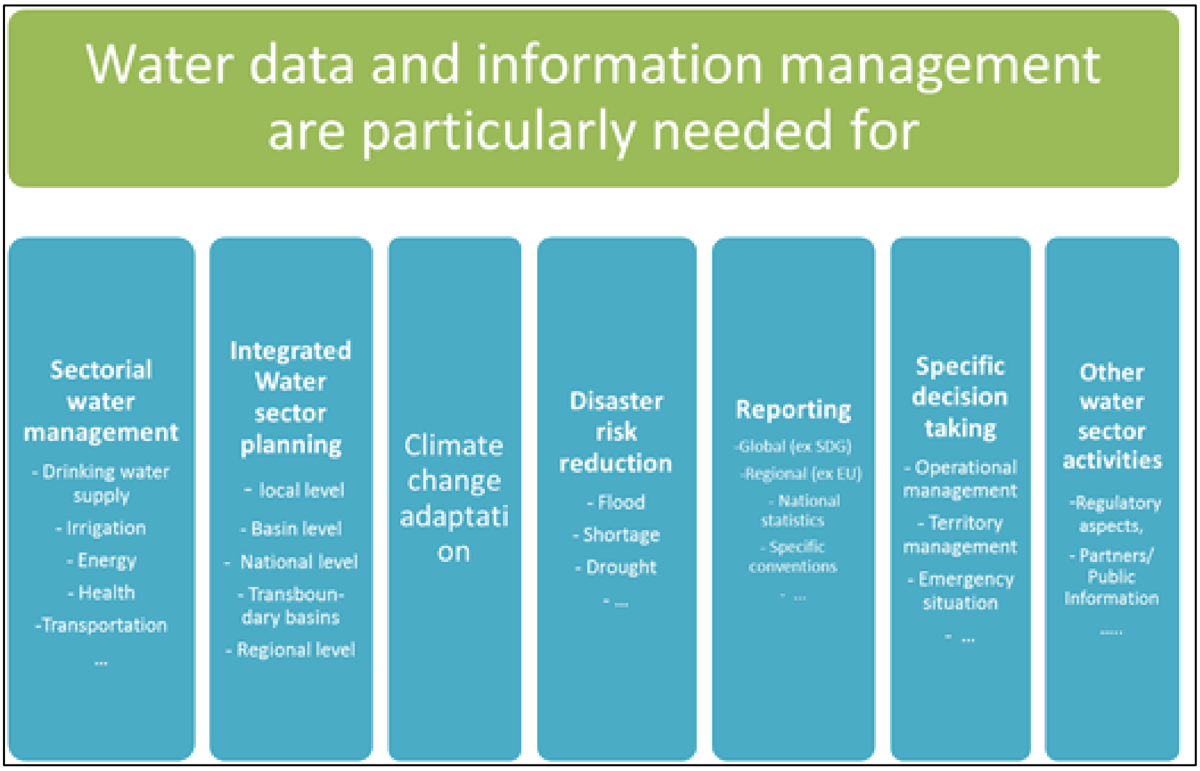

Figure 1: Different purposes for water data [3]

The regular exchange of data and information is also fundamental for establishing good cooperation between countries. This is particularly important for routine water resource operational management such as water sharing for irrigation, as well as for medium or long-term basin planning, with monitoring of the programme of measures and investments. Unfortunately, in most of the cases, data collection processes are limited: when they are available, existing datasets are usually fragmented, incomplete, dispersed and heterogeneous. In developing and maintaining monitoring and data exchange systems it is essential that the whole information system is supported by an appropriate institutional framework. This includes that the responsibilities of each actor are clear and that there is sustainable funding and resources. Especially in a transboundary setting assigning and sharing responsibilities is central.

C. The role of the Water Convention in monitoring and assessment

The 1992 Water Convention[4] is one of the most essential legal instruments for the monitoring and assessment of transboundary waters. The Convention's main goal is to prevent, control and reduce any transboundary impacts, which include significant adverse impacts on human health and safety, flora, fauna, soil, air, water, climate, landscape and historical monuments or other physical structures.

The Convention gives substantial directions on monitoring and assessment. Article 4 of the Water Convention states that 'The Parties shall establish programmes for monitoring the conditions of transboundary waters' while article 11 gives more detail on developing joint monitoring and assessment programmes. Article 6 states that 'The Parties shall provide for the widest exchange of

[3] INBO 2018. The handbook on water information systems administration, processing and exploitation of water-related data. https://www.inbo-news.org/en/file/314142/download?token=5uPk1dZ9

[4] https://www.unece.org/fileadmin/DAM/env/water/pdf/watercon.pdf

information, as early as possible, on issues covered by the provisions of this Convention' and article 13 provides the details for that. Article 16 deals with making information available for the public. Other parts of the Convention referring to monitoring and assessment include articles 3.1.b and h, 5.b, 8, 9.2.a, b, c, h, i and j, and 14. [5]

In defining and specifying information needs, establishing monitoring systems and assessing the status of waters, the Convention requires the setting of emission limits for discharges from point sources on the basis of the best available technology (BAT). It also requires authorizations for wastewater discharges and the application of at least biological or equivalent processes to treat municipal wastewater.

The Convention calls for best environmental practices (BEP) to reduce the input of nutrients and hazardous substances from agriculture and other diffuse sources. In addition, Parties must define water-quality objectives for the purpose of preventing, controlling and reducing transboundary impacts.

Obligations relating to the monitoring and assessment of specific river basins that stem from bilateral or multilateral agreements should be in line with the requirements of the Water Convention. In particular, joint bodies have a specific role in monitoring and assessment.

D. Mobilizing political support and ensuring uptake in policy development

The goal of M&A is to inform politicy and decision-makers about status and trends in water management. By making information more accessible and by exchanging information over borders, a deeper understanding of the water management situation and the interlinkages between various water uses and their socio-economic importance can be developed. This will enable to identify priority issues and to assess the effectiveness and efficiency of earlier measures. Such information can subsequently be included in policy development and implementation and can be used to mobilize political support. Accessible information can also help to raise awareness, e.g., in other departments but also over sectors.

In the international context, information can help to initiate and foster transboundary cooperation. Moreover, the information is necessary to identify progress in sustainable development. Reporting on the Sustainable Development Goal (SDG) 6 on water and sanitation, especially targets 6.3 (water quality), 6.4 (water use efficiency/water scarcity), 6.5 (IWRM) and 6.6 (water-related ecosystems), is consequently a means to assess progress, both at the national level and relative to other countries.

II Exchange of information and data : status and the challenges

A. Summary of main challenges identified in the reports submitted

Progress on transboundary cooperation is accounted as one of the indicators in achieving SDG 6 target 6.5 '*By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate*'. Indicator 6.5.2 tracks the proportion of transboundary basin area within a country that has an operational arrangement for water cooperation. For an

[5] http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_Text/ECE_MP.WAT_41.pdf

arrangement to be considered operational, four cumulative criteria need to be fulfilled, one of which is 'Regular exchange of data and information (at least once a year)'.[6]

In the first reporting cycle held in 2017-2018, 107 out of 153 countries sharing transboundary waters responded to the invitation to report on SDG indicator 6.5.2 by UNECE and UNESCO.[7] Beyond the indicator value, most countries reported on the details of their operational agreements, including their perceived main difficulties in fulfilling these criteria.[8] The joint report from UNESCO and UNECE *Progress on transboundary water cooperation: Global baseline for SDG indicator 6.5.2*, published in August 2018, provides an overview of the overall subjects on which data and information were reported being exchanged on.[9]

Reports submitted provide an indication of the main difficulties by region, based on the responses to the open question of Section II, question 6.e. Overall, reports from all regions mentioned harmonization, lack of resources and capacity as well as lack of agreements as the main difficulties to data exchange. Gaps on data availability are often related to technical infrastructure adequateness, which touches on issues of harmonization as well as of lack of resources and capacity. This includes common databases, monitoring networks, outdated scientific knowledge and also compatibility between the institutional framework in place at a national level and transboundary governance. Although these issues were mentioned across all regions, some regional nuances could be identified on the reports received.

The Pan-European region, which scored the highest level of transboundary water cooperation, reported harmonization and data availability as the main difficulties. In this regard, issues raised with include different standards – from methodology of data collection to frequency and format – to governance issues on a national level, which affects transboundary cooperation on data and information exchange. The lack of real-time data exchange, especially on water quality and data on discharges, was a common issue raised as a gap concerning data availability.

In the African region, which had a high rate of reports submitted and overall a good score on the existence of operational agreements, difficulties in data exchange that were raised touched mainly upon the lack of technical infrastructure and capacity, and consequently, harmonization and data quality. Among the specific difficulties raised were monitoring stations lacking or being insufficient, personnel and internet connection. Finally, lack of trust among riparian states and political instability was also specific to this region and the second most important cluster of difficulties identified.

---

[6] The four criteria are: (i) Existence of a joint body; (ii) Regular, formal communication between riparian countries (at least once a year); (iii) Joint or coordinated management plans or objectives; (iv) Regular exchange of data and information (at least once a year). See the *Step-by-step methodology for monitoring transboundary cooperation (6.5.2)* developed by UNECE and UNESCO as custodian agencies. Available online at: https://www.unwater.org/app/uploads/2017/05/Step-by-step-methodology-6-5-2_Revision-2017-01-11_Final-1.pdf

[7] For an overview of the results, see the interactive charts and maps at the SDG 6 data portal: https://sdg6data.org/indicator/6.5.2. Reports are available online at https://www.unece.org/water/transboundary_water_cooperation_reporting.html .

[8] For an analysis of the implementation of the Water Convention's requirements to exchange data and information, based on the reports submitted by Parties to the Water Convention, see pp. 42-44, UNECE, *Progress on transboundary water cooperation under the Water Convention* (online at: https://www.unece.org/environmental-policy/conventions/water/envwaterpublicationspub/envwaterpublicationspub74/2018/progress-on-transboundary-water-cooperation-under-the-water-convention/doc.html).

[9] See pp. 50-51, *Progress on transboundary water cooperation: Global baseline for SDG indicator 6.5.2 (*online at : https://www.unece.org/fileadmin/DAM/env/water/publications/WAT_57/ECE_MP.WAT_57.pdf).

Most reports received from the twelve countries from North, Central and South America did not provide an answer to this open question. However, among the specific difficulties identified among the answers is the lack of public access to information as a difficulty to data exchange and the lack of technical infrastructure.

Finally, the main nuance that stands out from the reports submitted by nine countries from Central, Western and South-east Asia is that lack of cooperation and trust among countries was what mostly stood out of the few reports received from the Asian region.

B. Types of data which are exchanged by region & other specificities

To better understand extensiveness and frequency of data exchange in practice, an assessment of data exchange in 25 transboundary basins across the world was conducted by the International Water Management Institute (IWMI). In Africa, 12 basins were assessed including the Nile, Volta and the Zambezi. The Danube, Rhine and Elbe basins were among the 7 basins assessed in Europe. Three basins were assessed in the Americas, namely Colorado, Tijuana and Lake Titicaca. In Asia, the Amu Darya, Mekong and Syr Darya were the three basins included in the study.

The results of the analysis point to high levels of data exchange on at least one core parameter (river flow). Nonetheless, consideration of a broader set of results produce a fairly mixed picture, with levels of exchange on some key parameters lower than expected.

Major findings include:

River flow data is widely exchanged among the basins at high frequencies. Approximately 75% of the basins assessed, exchange data on river flows. 40% percent of the basins exchanged river flow data at between real time and daily frequencies, 24% between monthly and annual frequencies and 12% at an *ad hoc* basis. Although frequency of exchange was varied it was largely regular.

Groundwater level and surface water abstraction data exchange was lacking or has exchanges at low frequencies. Among the basins assessed, 32% of basins shared groundwater level data and 28% exchanged surface water abstraction data. Groundwater data was mostly shared on request (16% of basins) or between quarterly and annual frequencies (16% of basins).

Water quality data is exchanged by less than half of basins (44%). Despite the centrality of water quality data to detect pollution levels detrimental to human life and the natural ecosystems, water quality parameters were shared to a lesser extent compared to river flows.

Some key factors identified as possibly impacting data exchange such as (i) the Water Cooperation Quotient (WCQ) (ii) Channel for data exchange and (ii) Presence of a data sharing protocol, did not appear to have an impact of the level of data exchanged.

In conclusion, the frequency of exchange was highest for river flow data compared to groundwater and surface water abstraction data exchange. *Ad hoc* exchanges were also observed, pointing at irregular data exchanges. The range or types of data exchanged is largely limited and exchanged at varying frequencies across different basins.

III Strategic approach to monitoring and assessment

The Strategies for Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters[10] that were published in 2006 provide an approach for developing a Monitoring and Assessment system in a transboundary context. The Strategies starts from the notion that decisionmakers not only need to know about the status and trends in the water system, but also need to know about the uses and functions of the water system, the way they influence water management and the options for mitigating problems. The Driving Forces–Pressures– State–Impact–Responses (DPSIR) framework (Figure 1) is chosen to describe these different elements.

A. DPSIR framework

The DPSIR framework assumes that social, economic and environmental systems are interrelated. These links are illustrated conceptually by driving forces of environmental change (the sources of a problem, like households or agriculture, and the way they produce or use the problem, like wastewater or application of fertilizers), which create pressures (e.g. the waste water that flows into the surface water, treated or untreated, or the amount of nutrients that runs off from the land into the surface water or seeps into the ground water) on the environment. These in turn affect the state of the environment (e.g. depicted by concentrations of nutrients or organic matter). The subsequent changes in status, or “impacts”, include impacts on ecosystems, economies and communities (e.g. changes in biodiversity or changes in water use, like a drinking water company that has to apply extra treatment). The negative impacts will eventually lead to responses by society, such as the development of policies for river basin protection. If a policy has the intended effect, its implementation will influence the driving forces, pressures, status (state) and impacts. Aiming at Driving forces this may be done by, for instance, promotion of best agricultural practices. Aiming at Pressures, applying improved wastewater treatment may be a good measure. An example of a measure to change the Status is application of calcium to fight acidification of lakes. Remediation of Impacts is done by, for instance, active fishing of specific fish species that maintain turbidity of the water by stirring up sediments.

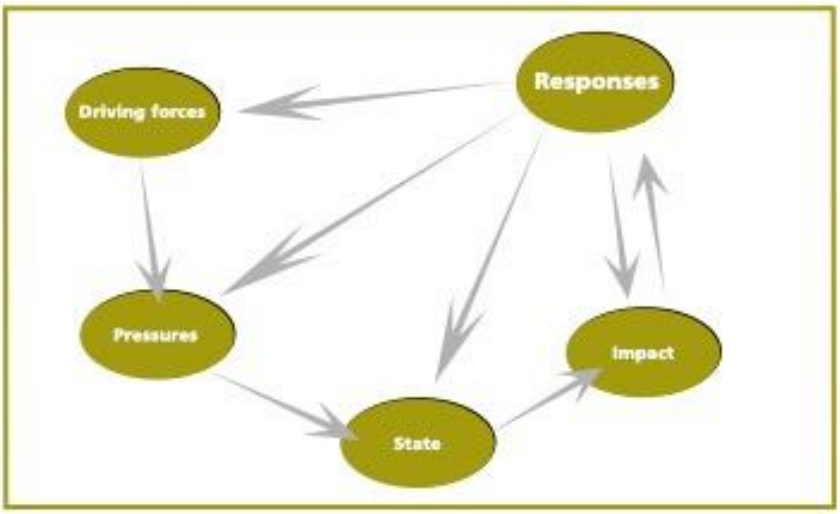

Figure 2: The Driving Forces–Pressures–State–Impact–Responses (DPSIR) framework

[10] https://www.unece.org/index.php?id=11683

B. Principles and approaches

The Strategies furthermore adopt the River basin approach that takes the river basin as the natural unit for integrated water resources management in which rivers, lakes and groundwaters interact with other ecosystems.

The Strategies furthermore describe relevant international legislation and commitments that should be taken into account. It also describes the institutional framework as well as funding that is needed for implementing and maintaining an M&A system at national and transboundary level.

The Strategies also promote a step-by-step or ladder approach. To make the best use of available resources and knowledge, priorities for monitoring and assessment and progressively are identified and agreed upon, proceeding from general appraisal to more precise assessments and from labor-intensive methods to higher-technology ones. Such a step-by-step approach can also help to specify the information needs and thus focus the assessment activities so that they are as effective as possible.

Models can be used to screen alternative assessment policies and monitoring strategies, optimize network design, assess the effectiveness of measures, and determine the impact on water bodies and the risks to human health and ecosystems. Models play an important role in flood forecasting and travel time calculations in accidents and spillages.

The use of pilot projects can help to test different approaches and select preferred ones. They can also act as examples to mobilize support from different stakeholders.

C. Monitoring and assessment cycle

The process of developing an M&A system is portrayed in the Strategies through the monitoring and assessment cycle (Figure 3). Monitoring and assessment of watercourses, including transboundary waters, follow a certain sequence of activities. The outputs produced by each of the activities are used in the consecutive activities of the cycle. Ideally, at the end of the cycle, the information needed for planning, decision-making and operational water management at local, national and/or transboundary levels is obtained in the form of a report or other agreed-on format. It should also become clear what kind of information is still needed for better decision-making and other water management tasks, given that policies and/or targets may have changed in the meantime. Thus, a new cycle would start leading to redefined or fine-tuned information needs, an “upgraded” information strategy, and so on.

Figure 3: Monitoring and assessment cycle

In the information cycle, going from information required to information obtained, the following activities are distinguished:

1. Information users, as part of the information cycle, should, in co-operation with information producers, decide upon the characteristics of the information that is needed: the information needs;
2. Information producers will, in co-operation with information users, decide upon the best way (i.e. strategy) to collect information with a specified (required) quality in the most efficient and cost-effective way;
3. A monitoring plan can be the outcome of the information strategy, but this is not inevitable as other sources of information exist; other programs to collect data can be developed in this step. The information cycle can therefore be used as a generic framework for designing information collecting systems;
4. The actual collection of data is the next step in the information cycle. Depending on the type of data and information needed, the data may be collected through, for instance, monitoring, models, or literature survey;
5. The collected data are analyzed, and the results are interpreted relative to the information needs. Information statements are made on this basis. The goal of the data-analysis is to mold the information in a form that the information users can utilize;
6. The resulting information is presented and transferred to the information users in a proactive manner. Science is linked again to water management in the activity of information utilization. This again, requires a dialogue to ascertain that the information is interpreted in a way that reflects the actual situation.

D. Testing of the Strategies

Prior to the development of the Strategies, three technical guidelines were developed:

- Guidelines on Monitoring and Assessment of Transboundary and International Lakes: UNECE Working Group on Monitoring and Assessment (2002)[11]
- Monitoring and Assessment: Transboundary groundwater guidelines (2001)[12]
- UNECE Task Force on Monitoring and Assessment: Guidelines on Monitoring and Assessment of Transboundary Groundwater (2000)[13]

These guidelines go into more detail on the specifics of developing a monitoring programme for Lakes, groundwater and rivers respectively. The characteristics of the different types of water bodies require different approaches, especially for ways of sampling, frequencies and selection of monitoring locations.

Early versions of the three different guidelines were tested in several pilot projects. The goal of the pilot projects was to test the guidelines and to demonstrate their applicability, to assist countries in their implementation, and to identify gaps and indistinctness in order to propose possible improvements for the guidelines.

From the pilot projects it was concluded, among others, that obtaining formal commitment for developing a transboundary monitoring system took a long time. Furthermore, expectations about the process and outcome differed greatly at the beginning of the pilot projects. The connection that was established in the pilot projects between water management and monitoring was highly appreciated. Application of the DPSIR approach in the pilot projects enabled explaining of the cause–effect relations and distinguishing between the different aspects of issues.

Based on the results of the pilot projects the technical guidelines were finalized. At a later stage, the overall approach from the guidelines was condensed into the Strategies.

IV Technical guidance and standards

A. The need for standards and quality management

Within the context of integrated water resources management, where decisions are increasingly being made in coordination with relevant stakeholders, it is imperative that accurate data and information be accessible in a timely manner to facilitate informed decision- making, especially in transboundary context. Research on the global water cycle and the effects of climatic variability and change on the availability of water resources requires the sharing and use of data at global level. To support such analyses and to facilitate consistency across borders, it is essential that the data be compatible, comparable and of known quality [14]. To this end, the use of standards and quality management of the whole process of monitoring and data sharing is important.

B. Standards

Standards are necessary to secure the compatibility, comparability and quality of data and information. A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and

[11] https://www.unece.org/index.php?id=20166
[12] https://www.unece.org/index.php?id=13026
[13] https://www.unece.org/index.php?id=12609
[14] Also see the report 'UNECE Task Force on Monitoring and Assessment: Quality Assurance', available at http://www.unece.org/index.php?id=12604

services are fit for their purpose, preferably based on an International Organization for Standardization (ISO) standard. The aims and benefits of standards are:

- Improve quality and trust
- Enable exchange of data
- Increase comparability of measurements
- Improve understanding uncertainty

The process thus becomes outcome and information oriented. Moreover, standards are highly important in the transboundary context. Characteristics of include are:

- performance focused
- precise
- complete
- unambiguous,
- state of the art
- comprehensible to qualified person non having participated in their development

In this respect, in a transboundary setting it is important that there is a standard setting organization to oversee the process and that there are procedures to support this task.

The World Meteorological Organization (WMO) is a standard setting organization that aims to ensure the quality of data and to ensure that data are available where and when needed [15]. As part of this endeavor, WMO has developed a series of hydro-meteorological guidelines and regulations. These are listed in Annex 1.

C. Quality Management in the context of Transboundary Water Resources Assessment

Quality management, and connected to that quality assurance and quality control, has four major benefits:

- It enables better management of the process and a more effective organization
- It leads to employee satisfaction and commitment to the organization
- It improves the quality of products and services.
- It improves customer satisfaction and the image of the hydrological services

Implementation of quality management systems will assist hydrological services in the provision of good management practices and ultimately will enhance confidence in the quality of their data, products and services. The process of quality management is part of the Monitoring and Assessment Cycle (Figure 3) and includes the following elements:

- Definition of the goals (monitoring, management, environmental, etc.)
- Information requirement (including acceptable uncertainty)
- Value chain holistic approach (QM embedded in the whole system, not isolated in the individual steps)
- Selection of variables to be monitored
- Processes (incl data rescue, data validation)

[15] The WMO Convention, Art.2 describes this as follows: “To promote standardization and to promote activities in operational hydrology and close co-operation between Meteorological and Hydrological Services.”

- Data handling and management
- Institutional arrangements in support to QM implementation

V Developments in technology and data access relevant for monitoring and assessment

An initial expert assessment of the developments in monitoring and assessment (M&A) since the publishing of the M&A Strategies developed under the Water Convention revealed that the general approach of developing the M&A system linked to the overall water management process is still valid. Important development lies in:

- More open data and related recommendations
- (Technological) developments over past decade relevant for M&A
- International databases and models where certain information can be found

A. More open data and related recommendations

Increasingly, guidelines and common standards for water information and for basic water analyses become available. Moreover, large amounts of spatial and other data has become easily accessible on-line (for example, through Google Earth Engine.[16]

The communication possibilities have improved which allows for easier involvement of various stakeholders in processes of water management and related information flows. The options for collecting information have increased, allowing for a more diverse information strategy. This translates to the data collection, where there are more diverse and often cheaper options for monitoring. Options for data management and analysis have improved. Specifically, GIS provides many different tools for managing and analyzing the data as well as for exchanging data. Also reporting options have widened and it has become easier to reach out to wider audiences though websites and social media.

These developments goes hand in hand with a growing realization of the importance of information worldwide. Growing populations, more water-intensive patterns of growth, increasing rainfall variability, and pollution are combining in many places to make the availability of fit-for-purpose water one of the greatest risks to poverty eradication, peace and all three dimensions of sustainable development. Floods and droughts already impose huge social and economic costs around the world, and our climate is driving increases in the frequency and severity of water-related extreme events.

SDG6 outlines some of the key actions that the world needs to take on water, including providing universal access to services, improving water quality, increasing water-use efficiency, protecting and restoring water-related ecosystems, and more broadly, implementing integrated water resource management at all levels, including through transboundary cooperation. These actions, however, depend on decision makers having access to and being able to use information and data that in many places is insufficient, not being shared, of uncertain quality, or simply does not exist. Moreover, the OECD water governance principles call for evidence-based decision making in water management.

[16] https://earthengine.google.com/

B. Technological developments over the past decade relevant for monitoring and assessment

Since the strategies report was published, several developments have taken place that mostly influence the way we can collect data and information, especially technological developments. Some of the developments have not matured entirely and for some, good examples exist. General developments include those described below.

Remote sensing and Geographical Information Systems (GIS)

Remote sensing (RS), and especially satellite imaging has developed substantially.[17] Advantages of RS are the large scale that can be covered and the fact that it does not require in-situ visits. Disadvantages include the fact that clouds hinder satellite imaging, the level of detail is relatively low, and the temporal coverage may be limited. Also, application for, for instance, water quality is limited.

Combined with GIS, satellite images can be used to provide good information on, among others, vegetation and soil moisture. Models in combination with GIS provide good opportunities to identify hot spots and show geographical relationships. Also, much open access data are available for GIS and GIS can be a good basis for sharing and exchanging data.

Emission registration

Emission registration by companies provide a good source of information, particularly for water quality purposes. This entails obliging companies to report on their emissions, discharges and losses to air, water and soil. Such an obligation can be part of the operating license.

Such a registration system covers the point source pollution. For diffuse pollution, various methods exist that enable calculating pollution loads from various sources, including agriculture and road and rail transport.

With this information, estimates can be made of the various sources of pollution. This in turn provides information on where measures can be effective.

Citizen science

Citizen science is a process by which everyday people take an active role in scientific discovery, joining forces with researchers to answer important science questions. In general, it entails asking citizens to support the research. Narrowing down to monitoring, citizens can be asked to collect information. This can, for instance, be done by providing them with rather simple testing kits with which they can monitor water quality. It requires strong ownership by the citizens and sufficient training of the citizens.

Drones

Drones are vehicles that can be operated from a distance. A floating drone can, for instance, be programmed to make transects in a lake and sample or measure at a regular interval. This is in general cheaper and often more precise than a boat with some people that do the sampling. A submarine drone can take samples at different depths. These devices are largely still under development but are expected to develop quickly.

[17] Examples are provided in the report 'New avenues for remote sensing applications for water management: A range of applications and the lessons learned for implementation (Water Global Practice, June 2019)

Sensors

More and more, sensors become available that can measure certain determinants. This enables installing automated monitoring stations that collect data at regular intervals. Communication technology enables remote real-time collection of the data. Sensors can also be installed on ferry boats to collect regular transects, or on drones.

International databases and models where information can be found

More and more open data sources come available that can support evidence-based decision making. The annex gives an overview of several data sources.

VI Good procedures for data management and data exchange

At transboundary level, the exchange of information and data on a between countries is often difficult for structural reasons (particularly when there is no agreement or protocol between the countries on data sharing), and technical reasons (difficulties related to information collection, harmonization of data formats, definitions, analysis methods, frequency of data collection, density of monitoring networks and data processing). National authorities may also be reluctant to provide neighboring countries with information that they consider strategic, and the economic value of water used for hydropower, agricultural irrigation and navigation may increase this reluctance.

Both transboundary and national organizations are generally facing difficulties in organizing data access, processing and optimal use, with typical issues such as:

- How to organize the production of new datasets and the enhancement of existing ones, in order to generate information and useful services for decision-making purposes and inform partners and the public?
- What are the datasets that already exist, in what form, and how can they be accessed in a flexible and efficient manner? How can be preserved from deterioration and loss?
- What are the best ways to manage the multiplicity of data producers and available formats as well as the issue of comparing datasets that are often incomplete, dispersed and of variable quality?
- What legislative / institutional frameworks exist to organize the sharing of data among partners as well as the processing and dissemination of the results?
- etc.

About the global organizational scheme between the transboundary and the national levels

Considering that the water data management is first of all a tool to support water policy, its organization at transboundary level will depend to a large extent on the type of existing transboundary basin organizations and on the level of cooperation defined in the provisions of the agreements concluded between the countries. Indeed, a transboundary basin organization with an operative executive agency may have the possibility to allocate human and financial resources:

- To develop and manage the information system;
- To improve data exchange;
- To organize transboundary data processing and information dissemination;
- To support / complete the data production processes existing at national level.

However, when no transboundary executive agency with specific resources exists, it is then necessary to rely on the national organizations resource to support these processes, or on sustainable external resources. It has to be noted here that when the data exchanges rely on projects, the issue of sustainability of the implemented processes must be considered.

In any case, reminding that most of the data used for transboundary water resources management is generally provided by the national organizations (the part of data directly produced by the transboundary organization is often very limited), the transboundary information system should ideally be built relying on the national information systems with (direct) access to the datasets made available by national partners. This implies to reinforce the national capacities in data management and to develop the capacities to exchange comparable data and interconnect the partner information systems (interoperability), using common language (concepts/referential dataset) and common procedures.

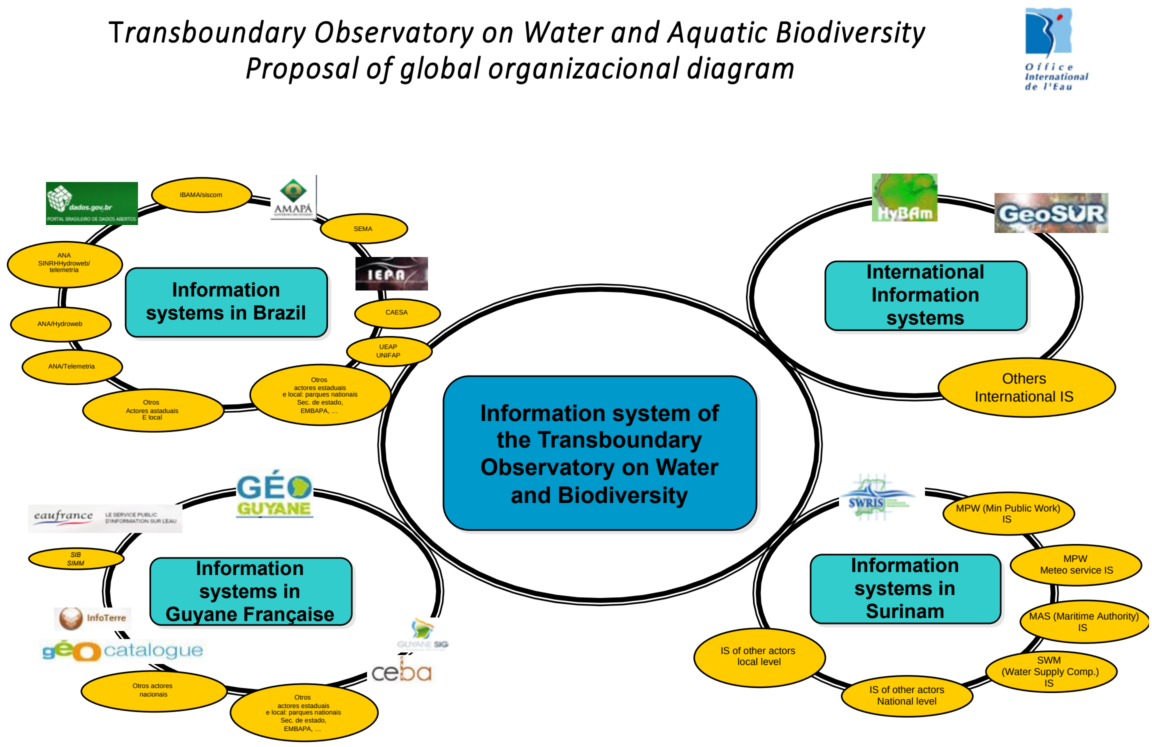

Figure 5: case study of the "Bio-Plateaux project" on Oyapock and Maroni transboundary basins between French Guyana, Brazil and Surinam [18]

[18] International Office for Water

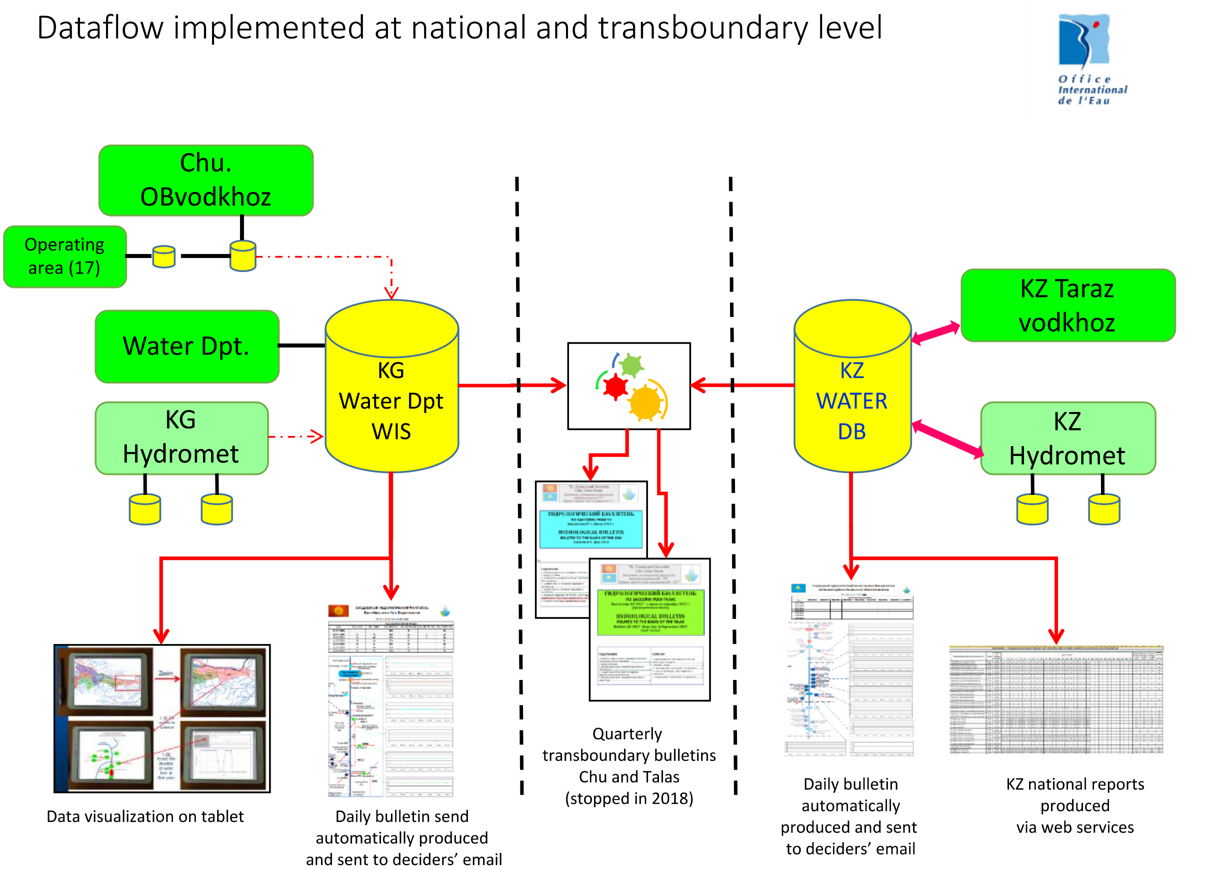

Figure 6: case study of Chu Talas basins shared between Kazakhstan and Kyrgyzstan [19]

Other key points to consider in order to reinforce data exchange and data management at transboundary basin level include:

- Introducing chapters related to data/information exchange in all framework agreements and action plan related to transboundary water resource management:
    - Reminding that data/information management is a key instrument for an effective transboundary water resource management

[19] International Office for Water

    - Considering the implementation of the SEIS principles:

The SEIS principles:

On 1st of February 2008, the European Commission adopted a Communication on SEIS (Shared Environmental Information System). The principles are described as follows:

- Information should be managed as close as possible to its source;
- Information should be collected once, and shared with others for many purposes;
- Information should be readily available to public authorities and enable them to easily fulfil their legal reporting obligations;
- Information should be readily accessible to end-users, primarily public authorities at all levels from local to European, to enable them to assess in a timely fashion the state of the environment and the effectiveness of their policies, and to design new policy;
- Information should also be accessible to enable end-users, both public authorities and citizens, to make comparisons at the appropriate geographical scale (e.g. countries, cities, catchments areas) and to participate meaningfully in the development and implementation of environmental policy;
- Information should be fully available to the general public, after due consideration of the appropriate level of aggregation and subject to appropriate confidentiality constraints, and at national level in the relevant national language(s); and;
- Information sharing and processing should be supported through common, free open standards.

- Building on the existing situation with information system and data management procedures, in reinforcing the capacity of the partners to manage/check and process their own data and in developing scenarios for data exchanges
- Reinforcing the capacities of each country/national basin to develop their own data management strategy (water data policy) and their own national/basin water information system and organizing the links between the transboundary and the national /basin water information systems
- Complementing data production by strengthening the traditional monitoring at transboundary level and by promoting the use of innovative monitoring technologies (earth observation systems, crowd sourcing, etc.)
- Developing new regular data exchange and information production processes and creating new services answering to the needs for transboundary water management
    - Sustainable scenarios of data exchange can be implemented at national and regional with the direct participation of the national and basin data producers looking for win-win relation and without additional work for them;
    - In conformity with the SEIS principles, the data producers should ideally expose a part of their data through web services and API (application programming interface), with open or limited access (following the level of confidentiality defined by the data producers/managers) to partners and/or to the public
- Developing the technical capacities to exchange comparable data and to interconnect the partner information systems (interoperability), using common language (concepts/referential dataset) and common procedures

  - The use of common regional definitions/procedure/datasets facilitate the exchange of comparable datasets (importance to develop regional referential datasets)
- Reinforcing human resources and technical capacities of the transboundary and national organizations on data production/management/dissemination, with development of specific training programs on water data management;

VII Financing and sustainability

Sustainable financing of monitoring systems is needed to be able to identify trends and changes over time and therefore to single out effects of policies and measures. Regional institutions are uniquely positioned to support transboundary activities, particularly information collection and institutional strengthening actions. Infrastructure assets, like monitoring stations, are typically (although not always) developed and managed at the national level, even when the data are shared by more than one country. That said, some activities can be implemented through national and regional actions, such as the installation and management of monitoring stations for weather information and analysis. In such a project the physical investments may be made on a national level, while a regional institution can provide capacity building for data collection and management, the institutional home for a database, analytical services, and information dissemination. As each basin is different, basin organizations need to identify the most suitable role in supporting financing the monitoring system for their basin. The costs of monitoring should be estimated before monitoring programmes begin, or when major revisions are planned. If the information needs are well defined, the estimate can be rather detailed. Monitoring costs can be divided into the following components:

- Network administration, including design and revision;
- Capital costs of monitoring and sampling equipment, automatic measuring stations and data transmission systems, construction of observation boreholes or surface water sampling sites and gauging stations, transport equipment, data processing hardware and software;
- Labor and other operating costs of sampling, field analysis of water- quality determinands and field measurements of water levels and discharge characteristics;
- Operating costs of online data transmission systems (e.g. water levels, accidental water pollution);
- Labor and other operating costs of laboratory analyses;
- Labor and associated operating costs of data storage and processing;
- Assessment and reporting (including joint work for transboundary waters); production of outputs, including geographic information systems (GIS) or presentation software and report printing costs.

The costs associated with administration as well as assessment and reporting are largely fixed and almost independent of the extent of the network. In contrast, the costs of other activities are strongly influenced by the number and types of sampling points, the frequency of sampling and the range of determinands to be analyzed. The number of sampling points can be multiplied with frequency and determinands to obtain rough cost estimates.

Because of the continuous character of monitoring, a long-term commitment to funding is crucial to ensure the sustainability of monitoring and assessment activities. This implies that funding should come mainly from the State budget. Donor-funded projects concerning transboundary watercourses should be coordinated with national authorities to ensure the continuity of monitoring activities which have been established in the project.

It is essential that monitoring and assessment programmes for transboundary waters be part of the national monitoring programmes of the riparian countries. The countries should take responsibility for all costs arising on their own territory. Moreover, the riparian countries should jointly decide on funding principles and make clear agreements regarding the funding of specific joint tasks.

Annex 1: Relevant materials for harmonization of hydrological data and information

Collection No. (year)	Title	Description
Policy documents		
No. 49 (2006)	Technical Regulations: Volume III - Hydrology	Define concepts and standard types of observations typically made within the hydrology domain
International exchange of data and products		
Cg-XII	Resolution 40 — WMO policy and practice for the exchange of meteorological and related data and products	"Members shall provide on a free and unrestricted basis essential data and products which are **necessary for the provision of services in support of the protection of life and property and the well-being of all the nations**…"
Cg-XIII	Resolution 25 — Exchange of Hydrological Data and Products	"Members shall provide on a free and unrestricted basis those hydrological data and products which are **necessary for the provision of services in support of the protection of life and property and the well-being of all the nations**…"
Vocabulary		
No. 385 (2012)	International Glossary of Hydrology	Establishing recognized international equivalents of hydrological terms, in order to minimise misinterpretations and consolidate the foundation for stronger international cooperation.
ISO 772 (2011)	Hydrometry — Vocabulary and symbols	
Measurements harmonization		
No. 1044 (2010)	Manual on Stream Gauging Vol. I: Fieldwork Vol. II: Computation of discharge	Standard procedures for stream gauging
No. 1028 (2008)	Manual on Low-flow Estimation and Prediction	
Data management		
-	WaterML2.0	data exchange standard in Hydrology which can basically be used to exchange many kinds of hydro-meteorological observations and measurements. The standard was developed through a harmonization

Collection No. (year)	Title	Description
		process by members of the joint OGC-WMO Hydrology Domain Working Group
-	Meteorological, Climatological and Hydrological (MCH) data base management system (DBMS)	NMHSs looking for a simple, customizable and license free solution to store, analyze and generate reports and maps on large amount of data.
Network design		
No. 168 (2008)	Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information	Chap. 2, section 2.4: Design and evaluation of hydrological networks
No. 1044 (2010)	Manual on Stream Gauging, Vol. I: Fieldwork	Chap. 2: Selection of gauging station site and network design
Data exchange		
No. 74 (2001)	Exchange of Hydrological Data and Products, Technical reports in hydrology and water resources	provide guidance to national hydrological services, and other agencies with responsibilities in water information management, on the practical implementation of Resolution 25 (CgXIII) on Exchange of hydrological data and products
-	WMO Information System (WIS)	- "extension of WMO's policy on the free and unrestricted international exchange of meteorological and related data and products to the entire domain of such data and products used globally." WMO Bulletin Vol. 55(4) - Based on Global Telecommunication System (GTS): "The coordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch." Technical Regulations (WMO No 49)
-	WMO Hydrological Observing System (WHOS)	portal to the online holdings of National Hydrological Services (NHS) around the world that publish their historical (OBS) and/or real-time (RT) data without restrictions or cost
No. 168 (2008)	Guide to Hydrological Practices, Volume I:	Chapter 10: Data storage, access and dissemination

Collection No. (year)	Title	Description
	Hydrology – From Measurement to Hydrological Information	
Metadata		
No. 1192 (2017)	WIGOS Metadata Standard	Aim to identify the conditions under which the observation (or measurement) was made, and any aspects that may affect its use or understanding, that is, to determine whether the observations are fit for the purpose.
Data quality		
No. 168 (2008)	Guide to Hydrological Practices, Volume I: Hydrology – From Measurement to Hydrological Information	Chapter 9: Data processing and quality control
ISO 9001 (2015)	Quality management systems - Requirements	Applies to all types of organizations. It doesn't matter what size they are or what they do. It can help both product and service-oriented organizations achieve standards of quality that are recognized and respected throughout the world.

Annex 2: Selected international initiatives:

United Nations Global Environment Monitoring System (GEMS)

The Global Environment Monitoring System for Water (GEMS/Water) is a programme that aims at collecting world-wide freshwater quality data to support scientific assessments and decision-making processes. In addition, GEMS/Water offers support and encouragement to developing countries wishing to establish monitoring programmes and conduct assessments of water quality, by providing capacity development via training, advice and assessment tools.

GEMStat hosts water quality data of ground and surface waters providing a global overview of the condition of water bodies and the trends at global, regional and local levels. At present, the growing database contains more than 4 million entries for rivers, lakes, reservoirs, wetlands and groundwater systems from 75 countries and approximately 4000 stations. Overall, data is available for the time period from 1965 to 2017 and about 250 parameters (see data and visualization sections for more information).

Countries and organizations voluntarily provide water quality data from their own monitoring networks. The water quality data available in GEMStat can be used for status evaluation, policymaking, research purposes or within the scope of education and training initiatives.

https://gemstat.org

Information System on Water and Agriculture of the United Nations Food and Agricultural Organization (FAO AQUASTAT)

AQUASTAT is the FAO global information system on water resources and agricultural water management. It collects, analyses and provides free access to over 180 variables and indicators by country from 1960. AQUASTAT draws on national capacities and expertise with an emphasis on Africa, the Near East, countries of the former Soviet Union, Asia, and Latin America and the Caribbean. AQUASTAT plays a key role in the monitoring of the Sustainable Development Goal 6 that sets out to "ensure availability and sustainable management of water and sanitation for all", and in particular indicators of target 6.4 on water stress and water use efficiency.

http://www.fao.org/aquastat/en/

SDG6 Data Portal Water Productivity Open-access portal (WaPOR)

FAO has developed WaPOR, a publicly accessible near real time database using satellite data that will allow monitoring of agricultural water productivity.

The beta release of WaPOR, was launched on April 20, 2017. Based on the methodology review process, a new version WaPOR 1.0 became available in June 2018, focusing first on the coarser resolution level (Level 1), covering the whole of Africa and the Near East at 250 m ground resolution and then the national / river basin level (Level 2) at 100 m resolution.

https://wapor.apps.fao.org/home/WAPOR/1

World Metrological Organization’s Hydrological Information Referral Service (WMO INFOHYDRO)

The Hydrological Information Referral Service (INFOHYDRO) provides hydrological information to experts, agencies and enterprises engaged in projects related to water-resource assessment, development and management.

INFOHYDRO has information on:

- Governmental and non-governmental organizations, institutions and agencies dealing with hydrology
- Hydrological and related activities of these bodies
- Networks of and data collected by hydrological observing stations

https://www.wmo.int/pages/prog/hwrp/INFOHYDRO/infohydro_index-NEW.html

International Groundwater Assessment Centre (IGRAC) for groundwater – Global Groundwater Model (IGRAC)

IGRAC, the International Groundwater Resources Assessment Centre, is a UNESCO center that works under auspices of WMO and is supported by the Government of The Netherlands. IGRAC specializes in regional- and transboundary-level assessment and monitoring of groundwater resources with a focus on managed aquifer recharge, groundwater governance and SIDS.

One of IGRAC's flagship products is the Global Groundwater Information System (GGIS) (https://www.un-igrac.org/global-groundwater-information-system-ggis). It is a web-based Geographic Information System, which supports the storage, visualization, analysis and sharing of groundwater data and information through map-based modules. The GGIS is a highly interactive system that can easily be enlarged with new thematic and/or regional (project) modules.

https://www.un-igrac.org

World Water Quality Assessment

The aim of WWQA pre-study was to develop and demonstrate a data and model driven methodology to identify current "hotspots" of deteriorating freshwater quality including

- types, intensity and sources of water pollution,
- potential impacts relating to human health and food security (freshwater fishery),
- main water quality data and information gaps, and
- strategies for future monitoring.

As a main outcome, the report 'A Snapshot of the World's Water Quality – Towards a global assessment' with accompanying Policy Brief summarizes the key findings of the pre-study. The methodology developed offers a baseline to measure progress, a framework for global assessment and a pathway towards sustainable solutions. This report will help bridge the gap between water quality, the inclusive green economy and the interlinked issues of sustainable development.

http://www.wwqa-documentation.info

World Water Data Initiative (WWDI)

The World Water Data Initiative is a global effort previously launched by the Government of Australia to promote hydrometry as a basis for implementing SDG 6 on access to clean water and sanitation.

The World Meteorological Organization (WMO) took on the leadership of the World Water Data Initiative at a meeting of the WMO Executive Council in Geneva, Switzerland in 2018.

The objective for the World Water Data Initiative is to improve cost-effective access to and use of water and hydro-meteorological data by governments, societies and the private sector through policy, innovation and harmonization. This objective will be pursued through practical measures under three pillars:

- 'Water Data Policy' pillar: how can societies have better and more equitable access to water data and tools, and capacity to use this information, to manage water better?
- 'Water Data Innovation' pillar: how can governments, societies and the private sector access reliable data about water that is adequate to their needs at the lowest possible cost?
- 'Water Data Harmony' pillar: how to reduce costs and complexity at the river basin and national levels by accelerating progress on common standards for water data and for basic water data metrics?

https://sustainabledevelopment.un.org/content/documents/13327HLPW_WWDI_Roadmap.pdf