CHAPTER III: ISSUES WATER ALLOCATION CAN ADDRESS

SUMMARY:

This chapter first discusses the main drivers of water management challenges today and in the future—particularly the need to respond to increased and competing demands for water and water-related services—and the resulting pressures on available water resources. It then examines how allocation approaches and frameworks can seek to address these challenges of water availability, variability and uncertainty, focusing particularly on interventions in transboundary contexts. Methods for balancing various water uses and needs when planning and implementing transboundary water allocation and potential reallocation are then proposed, including balancing historical, current and future uses.

1. Understanding the Drivers and Roles of Water Allocation in a Transboundary Context

Increased and competing demands for water and water-related services and the resulting pressures on the available water resources have resulted in growing attention towards water allocation during the past decades. The key driver behind the interest in water allocation globally has been the overall and ongoing growth in water abstractions, primarily due to population growth, economic development and changing consumption patterns. Basin "closure", i.e. complete allocation of all available water resources, is an increasingly common problem in many parts of the world. Due to higher water demand, there is also greater interaction between depletion and pollution of both surface and groundwater sources.[32] Water allocation can thus play an important role in addressing these major water issues of today and the future, many of which cross State and national borders. Moreover, it can be stated that "[a]ppropriate water allocation results in more socially and economically beneficial use of the resource while protecting the environment. Unsuitable or ineffective approaches drive water stress. Understanding water rights and water allocation is therefore key to understanding the solutions to global water stress".[33]

From the outset, water allocation must not be viewed as a race to delineate and claim access to the world's increasingly scarce and degraded freshwater resources. Rather, water allocation is one method of addressing water challenges in seeking to achieve more effective, sustainable and equitable integrated water resources management (IWRM). As emphasized in Chapter II, water allocation approaches, mechanisms and arrangements are best applied as a part of broader basin-level planning, management and transboundary cooperation. In many instances, demand management measures, efficiency improvements or finding alternatives from benefit-sharing can complement supply-focused allocation solutions towards achieving effective IWRM (see also Chapter IV). Moreover, environmental protection is increasingly central to allocation frameworks. In a survey of 27 Organisation for Economic Co-operation and Development (OECD) and key partner countries in 2015, environmental protection, or meeting ecosystem requirements, was the most frequently cited driver for both recent and ongoing national allocation reforms. It was followed by economic development, while equity in access to water, water quality concerns, climate change mitigation and adaptation, and the need to address water scarcity all featured in more than half of the cases as

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[32] Speed and others (2013).

[33] Tom Le Quesne, Guy Pegram and Constantin Von Der Heyden, "Allocating scarce water: a primer on water allocation, water rights and water markets", WWF Water Security Series, No. 1 (Godalming, United Kingdom, WWF-UK, 2007), p. 10.

well.[34] Transboundary water allocation is not and should not be considered a zero-sum game for available resources.

As a necessary basis for allocation decision-making, this chapter first discusses availability and variability of water resources now and in the future, including the outlook on climate change and exceptional circumstances such as droughts and floods. It will then present the different water use needs and functions with their associated characteristics that need to be taken into account when allocating water. The chapter also highlights the importance of understanding and addressing different factors impacting on allocable water, including water infrastructure, water scarcity, and water quality and environmental degradation. To conclude, the chapter discusses the importance of considering historical, current and future uses and balancing different water uses and needs.

2. Availability, Variability and Associated Uncertainty: Now and in the Future

a. Availability of surface and groundwater resources

Availability of freshwater resources for allocation in a transboundary context generally depends on the availability of renewable surface and groundwater sources (see Figure 6). Many different factors impact on water availability. Human activities directly affecting the availability of surface water resources for allocation consist of abstraction and water use, which may further be divided into non-consumptive and consumptive uses. Non-consumptive uses are generally described as releasing water back to the source after use or not abstracting water for use at all (e.g. recreation at water bodies, navigation) while consumptive uses remove the water from local sources (e.g. via irrigation and evapotranspiration in agriculture). However, change in the quality of the water released back to the source also effectively limits its reuse, too (for a detailed description on consumptive and non-consumptive uses, see subsection 3b below). In addition, water infrastructure, depending on its coverage and efficiency or leakage ratio, may further increase or decrease surface water availability. Climate change, water quality and ecosystem health also impact on availability, as detailed later in this chapter.

Aquifers are usually connected to surface water systems, which has implications for overall water availability. In areas with significant connectivity between surface and groundwater, high levels of groundwater abstraction can affect the availability of surface water as groundwater provides significant contributions to streamflow. The implications of this are twofold: first, assuring minimum water flows in a stream, e.g. for environmental flows (see subsection 3a of this chapter) requires control of groundwater allocations and abstractions; second, water allocation may be contingent on the level of depletion of groundwater resources in a transboundary setting, and may favour a shift from groundwater to surface water reliance or to one of enhanced/managed aquifer recharge.[35] Due to their non-renewable nature, fossil transboundary aquifers require careful consideration and assessment in their use and management in the specific context, including whether alternative water sources are available or not.[36]

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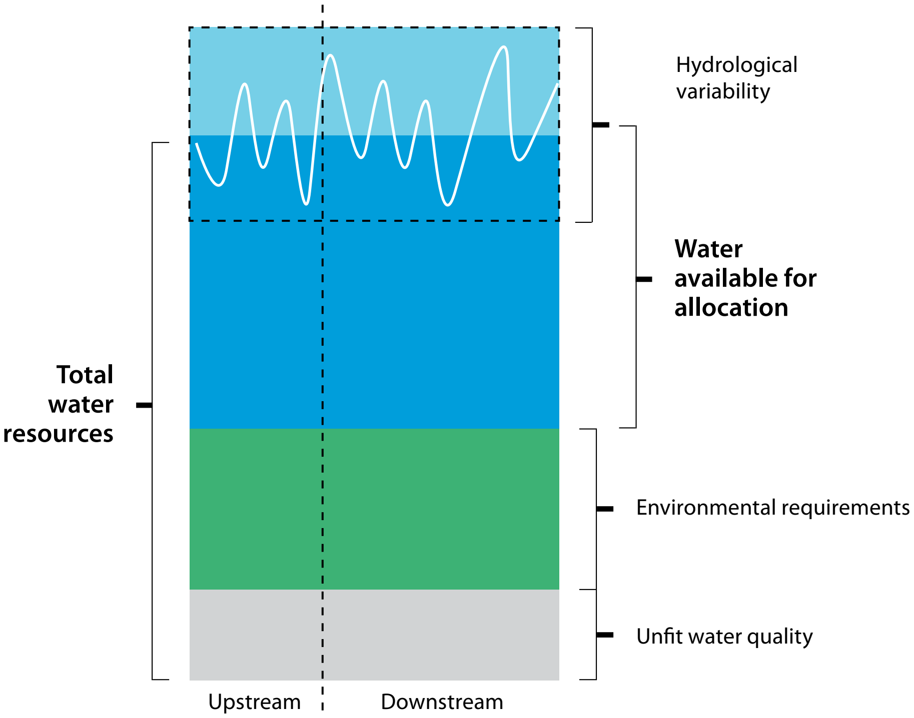
[34] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

[35] Aditya Sood and others, "Global environmental flow information for the Sustainable Development Goals", IWMI Research Report, No. 168 (Colombo, Sri Lanka, International Water Management Institute, 2017).

[36] UNESCO, "Non-renewable groundwater resources: a guidebook on socially-sustainable management for water-policy makers", Stephen Foster and Daniel P. Loucks, eds., IHP-VI Series on Groundwater, No. 10 (Paris, 2006).

FIGURE 6

Simplified diagram of available water and water for allocation in a transboundary context



Source: Organisation for Economic Co-operation and Development (OECD), *Water Resources Allocation: Sharing Risks and Opportunities*, OECD Studies on Water (Paris, 2015) (modified).

CASE STUDY 2: Spatial limitations to abstracting non-renewable groundwater from the Saq–Disi aquifer

The Saq–Disi sandstone aquifer (estimated area 308,000 km^2), shared by Jordan and Saudi Arabia, supplies water through the Disi water transport project (350 km) to Amman and other governorates in Jordan. Saudi Arabia uses the same basin to supply Tabuk and other cities, in addition to agricultural uses. Already significant in the 1980s, abstraction in more recent decades has increased. In the past decade, migration of large numbers of Syrian refugees into Jordan exacerbated the need for water. With the objective of achieving long-term sustainable management of this transboundary groundwater source with a low rate of contemporary renewal, the aquifer-sharing countries signed an agreement in 2015. More specifically, the agreement determines, first, protected areas in both countries—some 50 km long and 10 km (in Jordan) or 20 km wide (in Saudi Arabia)—where no groundwater investment projects are allowed, and second, managed areas where restricted, mutually agreed drilling standards are applied to reduce the effects on declining water level and on water quality. Moreover, in the managed areas, injection of any contaminant is prohibited in order to protect groundwater.

A technical committee that emanated from the Saudi Arabia–Jordan Joint Water Committee is to supervise the implementation of the provisions, monitor groundwater (withdrawal, water levels and quality) as well as collect and analyse data, information and studies. Among future challenges in this mainly arid zone is the severe drawdown in the water level that gradually reduces the aquifer's capacity to provide water while demands have increased. The depletion has led to restricting groundwater use from Saq–Disi aquifer for household and drinking water purposes only. Other water sources are being developed in the countries, including desalinization and water reuse, although these are not part of the agreement's scope.

Groundwater availability is predominantly affected by human activities and access to the aquifer systems, including availability of appropriate infrastructure and technology. Due to climate change, groundwater demand is expected to grow further in certain regions around the world, due to the higher demand for, and temporal variability of, surface water flows.[37] In various regions, groundwater is a more important source of water supply than surface water. With 592 transboundary aquifers identified globally, groundwater provides drinking water to at least 50 per cent of the global population and constitutes 43 per cent of the global irrigation water use.[38] At the same time, 20 per cent of the world's aquifers are estimated to be overexploited and many of them are contaminated.[39] Groundwater rights may also be less well defined, or not enforced, compared with surface water rights, implying that groundwater may be exploited at the expense of surface water in the vicinity of shared transboundary water courses, with indirect implications for surface water availability.[40] Increases in groundwater abstraction coupled with shifts of increasing variability in aquifer recharge have further highlighted the need for the conjunctive management and regulation of surface and groundwater systems.[41]

Alternative water resources may increase the volume of surface and groundwater available in a given State, in another area or for a specific user, and thus indirectly contribute to the overall volume allocable with other parties. Examples of alternative water resources include inter-basin water transfers,[42] managed aquifer recharge (groundwater recharge enhancement), desalinated water, harvested rainwater, non-renewable groundwater, return water in irrigation, reclaimed and recycled wastewater, and utilizing soil water or precipitation in areas previously irrigated. It should be noted, however, that given the externality of many of these alternatives, their use can potentially increase the stress or scarcity of water availability in other basins.

b. Managing temporal and spatial variability in transboundary water allocation

Natural hydroclimatic conditions form the basis of available water resources of a region (e.g. dry or humid). Water resources availability varies *intraannually* (between seasons) and *interannually* (between years), over decades and longer periods of time, due to climate oscillations. Hydrological flow regimes, and thus availability of water for allocation, are influenced by the main water sources. Snowmelt sources commonly have a pronounced spring flooding period, whereas in glacier-fed rivers from high mountains a higher flow is better sustained over time. Rivers with an important base flow from groundwater, or with big lakes in their basin, are more stable providers of water.[43] Hydroclimatic shifts to these flow regimes may be the result of natural variation or driven by human activities. Human-induced shifts are exemplified globally by climate change and regionally, for example, by changes in land cover due to deforestation, afforestation, agriculture or urbanization resulting in changes in run-off, infiltration and evapotranspiration.

Managing temporal variability and trends in water resources availability for transboundary water allocation requires long historical series, as well as: availability, access and sharing of data; solid understanding of different water resources and their uses and changing demands; allocation mechanisms that are flexible and

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[37] Richard G. Taylor and others, "Groundwater and climate change", *Nature Climate Change*, vol. 3 (2013), p. 322–329.

[38] IGRAC, "Transboundary aquifers of the world map", 2015.

[39] Tom Gleeson and others, "Water balance of global aquifers revealed by groundwater footprint", *Nature*, vol. 488 (2012), p. 197–200.

[40] Richard Owen, *Groundwater Needs Assessment: Limpopo Basin Commission LIMCOM* (n.p., Southern African Development Community; BGR; Africa Groundwater Network; Waternet, 2011).

[41] Jonathan Lautze and others, "Conjunctive management of surface and groundwater in transboundary watercourses: a first assessment", *Water Policy*, vol. 20, No. 1 (2018), p. 1–20.

[42] It should be noted here that inter-basin transfers are "associated with both positive and negative impacts to water-exporting, water-transmitting, and water-importing regions", see Purvis and Dinar (2020). For further information, see, generally, Gupta and van der Zaag (2008); C. D. Snaddon, B. R. Davies and M. J. Wishart, "A global overview of inter-basin water transfer schemes, with an appraisal of their ecological, socio-economic and socio-political implications, and recommendations for their management", TT 120/00 (Pretoria, Water Research Commission, 1999).

[43] UNECE, *Second Assessment of Transboundary Rivers, Lakes and Groundwaters* (2011).

adaptable to adjust to and cope with shifts in hydroclimatic patterns, including exceptional circumstances such as droughts and floods; integration of appropriate conflict resolution mechanisms or dispute resolution processes; and fit-for-purpose infrastructure for both surface and groundwater (e.g. dams and reservoirs, and managed aquifer recharge), as detailed below.

Besides temporal variations, upstream–downstream basin positions are spatial factors resulting in differences in the surface water available for allocation in transboundary contexts. Impacts of climate change and exceptional circumstances, such as droughts and flooding, also typically vary in different parts of large river basins. Addressing the resulting issues in a way that respects the principles of equitable and reasonable utilization and no harm is at the very heart of transboundary water allocation and broader cooperation, as discussed in other sections of this Handbook. In some aquifers, most of the groundwater recharge may occur in one country, whereas the groundwater may be extensively abstracted in the other areas. It is thus also necessary to consider groundwater recharge and its effects on surface water availability in allocation arrangements.[44]

c. Climate change as a cross-cutting challenge

Impacts of climate change on water resources

Climate change is unequivocally a major challenge for water resource use and allocation throughout the world.[45] The impacts of climate change are primarily felt via changes in the hydrological cycle.[46] Climate change causes shifts in timing, location, amount and forms of precipitation (both in mean precipitation and between seasons and years), affects mean annual stream flows and increases the frequency and intensity of extreme events such as droughts and floods. Climate change impacts on water resources are thus both episodic, such as extreme weather events like droughts and floods, long-term and permanent, as evident in changes in flow regimes and absolute water balances (Figure 7).[47]

Rising temperatures increase surface water evaporation, evapotranspiration from vegetation affecting agricultural water use and glacial ice melt, for example. Glacial melting in the world's major mountain ranges, the sources of rivers supplying 1.5 billion people worldwide, may temporarily provide more water downstream but deplete those water towers over time.[48] Some areas in the world may experience wetter conditions due to climate change, but those often come with their own challenges and trickle-down effects such as increases in flooding and nutrient leaching from land. Climate change further affects the availability and condition of freshwater resources by aggravating other growing pressures on water resources such as water scarcity, deteriorating water quality and ecosystem degradation.[49] It thus also complicates achieving the target of SDG 6 of ensuring safe and sustainable access to water for all.[50]

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[44] Speed and others (2013).

[45] UNESCO WWAP, *The United Nations World Water Development Report 2020*.

[46] OECD, *Water and Climate Change Adaptation: Policies to Navigate Uncharted Water* (Paris, 2013), p. 23.

[47] Jacob Schewe and others, "Multimodel assessment of water scarcity under climate change", *Proceedings of the National Academy of Sciences*, vol. 111, No. 9 (2014), p. 3245–3250; UNECE and International Network of Basin Organisations (INBO), *Water and Climate Change Adaptation in Transboundary Basins: Lessons Learned and Good Practices* (Geneva, United Nations, 2015).

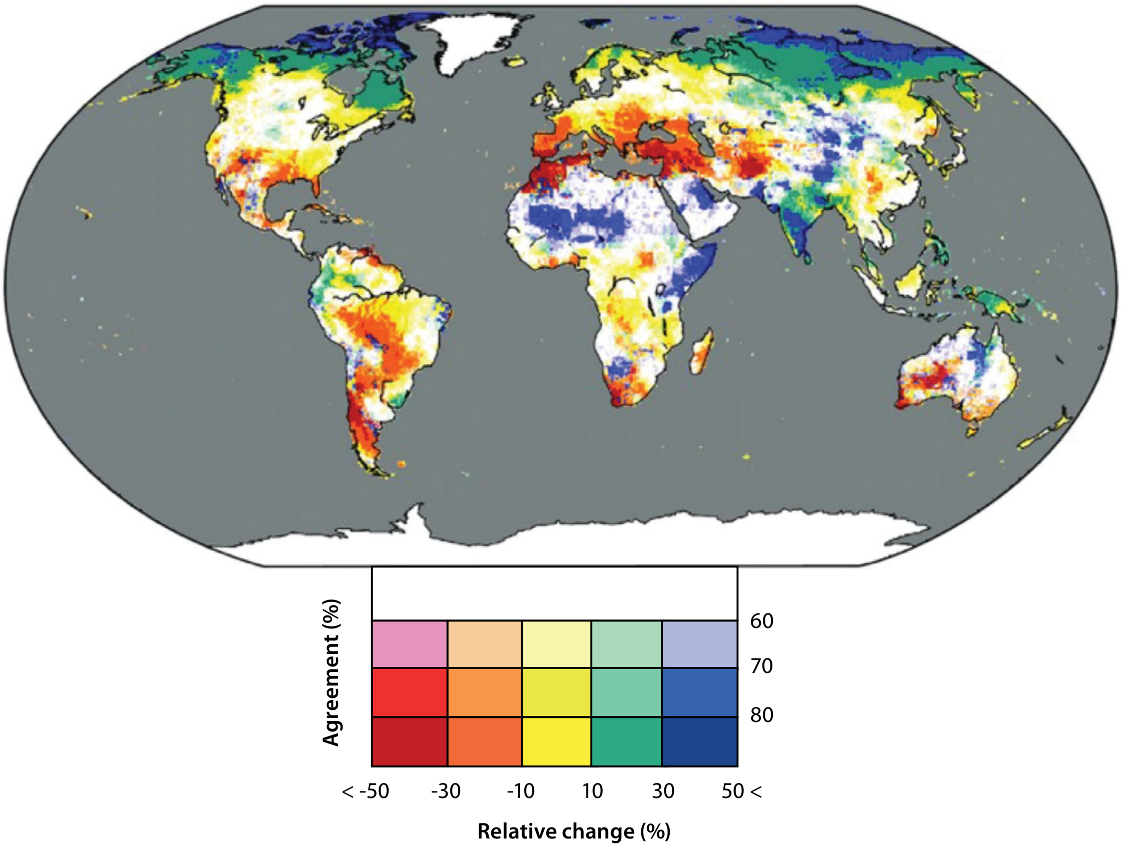
[48] Daniel Viviroli and others, "Increasing dependence of lowland populations on mountain water resources", *Nature Sustainability*, vol. 3 (2020), p. 917–928.

[49] UNESCO WWAP, *The United Nations World Water Development Report 2020*.

[50] See https://sdgs.un.org/goals/goal6.

FIGURE 7

Percentage change of mean annual streamflow for a global mean temperature rise of 2°C above 1980–2010 levels (2.7°C above pre-industrial levels)



Source: Blanca E. Jiménez Cisneros, Taikan Oki and others, "Chapter 3: Freshwater resources" in C. Field and others, eds., *Climate Change Impacts, Adaptation and Vulnerability Part A* (Cambridge, Cambridge University Press, 2014), p. 229–269.

Note: Colour hues show the multi-model mean change across five general circulation models (GCMs) and 11 global hydrological models (GHMs), and saturation shows the agreement on the sign of change across all 55 GHM–GCM combinations (percentage of model runs agreeing on the sign of change).

Transboundary water resources management and cooperation in a changing climate

The 2015 Paris Agreement to the United Nations Framework Convention on Climate Change and SDG 13[51] both urge countries to collaborate on taking urgent action in combating climate change and its impacts, including both mitigation and adaptation measures. As climate change is expected to alter the desired and actual uses of water, it calls for adaptation measures in water resources management at the national, transboundary and regional scales. Types of adaptation measures include legislative and regulatory instruments (e.g. laws, regulations and agreements based on international conventions), financial and market instruments (e.g. licences, permits and taxes), education and informational instruments (e.g. public awareness campaigns), policy instruments (e.g. intersectoral mechanisms for cooperation and agreement of different sectoral policies, etc.), as well as structural (e.g. flood protection infrastructure) and non-structural

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[51] See https://sdgs.un.org/goals/goal13.

(e.g. information exchange and nature-based solutions such as wetland restoration) measures.[52] In practice, examples of adaptation measures can range from demand management strategies, including structural changes in economy (e.g. shift to crops, sectors or technologies using less water), new technical standards (e.g. best available techniques (BAT)), metering and pricing, and introducing other incentives for water-saving and improving water-use efficiency, to trading of water rights[53] and ecosystem conservation and restoration.

Climate change poses the following specific challenges for transboundary IWRM, among others:

- increased uncertainty regarding availability and variability of shared water resources;
- potentially unequal regional distribution in climate-change-induced effects and resulting impacts;
- changing water demands (e.g. agricultural water demands are sensitive to increase in evapotranspiration);
- resulting growing tensions, even in areas where transboundary interaction in the past has been characterized by cooperation;
- worsening of water quality and dissemination of water-related diseases;
- increasing costs for water management, especially if there is a lack of transboundary and cross-sectoral cooperation in prioritizing the adaptation measures.

At the same time, enhanced transboundary cooperation provides many benefits for climate change adaptation. Benefits primarily come in the form of potential for joint climate and socioeconomic scenarios, vulnerability and impact assessments, disaster risk reduction strategies and response measures, reducing uncertainties through exchange of data, sharing costs and benefits, better prioritization of measures and improving/developing broader regional cooperation and dispute settlement mechanisms.[54] Joint bodies are central forums for developing and implementing adaptation strategies, but their operationalization lies with the member countries. Conversely, some national adaptation measures may have transboundary impacts and thus require transboundary cooperation.[55]

Transboundary water allocation in a changing climate

Climate change must be approached as a cross-cutting challenge for effective transboundary allocation. It is a potential risk multiplier that may necessitate adjustment of existing—and careful drafting of any new—transboundary water allocation agreements and arrangements. Ideally, transboundary allocation arrangements should factor in the increased uncertainty, inter- and intraannual variability of precipitation, run-off and, in some cases, step reductions to cope with increasing frequency and extremity of drought and flood events. Measures such as adaptative capacity and flexibility can assist in addressing these issues, as outlined in Chapter V, section 6. Making transboundary allocation arrangements climate resilient also requires strong coordination mechanisms between different levels of governance, sectoral policies and stakeholder groups.[56] They need to be aligned with climate change adaptation and mitigation efforts, taking into account the different water requirements of different energy options, such as hydropower, solar and

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[52] UNECE, *Guidance on Water and Adaptation to Climate Change* (Geneva, United Nations, 2009).

[53] UNESCO WWAP, *The United Nations World Water Development Report 2020*.

[54] UNECE and INBO (2015).

[55] UNECE, *Guidance on Water and Adaptation to Climate Change* (2009).

[56] See, generally, Garrick, *Water Allocation in Rivers under Pressure* (2015); John Matthews, "The test of time: finding resilience across climate boundaries", in *Green Growth and Water Allocation: Papers presented at a workshop held on 22–23 November 2012 in Wageningen, the Netherlands*, Sophie Primot and others, eds. (n.p., Netherlands National Committee IHP-HWRP; Netherlands National Commission for UNESCO, 2013), p. 119–129.

wind power and biofuels.[57] Renewable energy can drive sustainable water use and allocation and vice versa when the synergies and trade-offs in the water-food-energy-ecosystem nexus are appropriately addressed.[58]

d. Drought

Impacts of drought in transboundary settings

Drought, along with flooding, is an example of exceptional, though ever more frequent, circumstances that transboundary water allocation needs to address. Drought can refer to prolonged absence or marked deficiency of precipitation over an extended time (meteorological drought), or a deficiency of groundwater, stream water or lake storage (hydrological or blue-water drought), or a deficiency in water stored in the soil or vegetation (agricultural or green-water drought), as consequences of abnormally dry weather periods.[59] Beginning as hydrological events that cause water shortages, how droughts evolve and what their impacts are and who/what they impact on depend on the State and management of human systems.[60] Drought can result in loss of harvest and livestock, food insecurity and decreased domestic water supply that lead to famine, malnutrition, poor hygiene and stunting, with children and women being the most vulnerable. Prolonged drought conditions may cause collapse of social structures and lead to forced migration and be a significant contributing factor to conflict (eg. In Syria).

CASE STUDY 3: **Allocation lessons from the United States' governance of intracountry cross-border rivers: drought contingency plan on the Colorado River**[61]

Approximately 1,400 miles long and flowing through seven States of the United States and into Mexico, the Colorado River drains roughly one-twelfth of the land area of the contiguous United States. The Colorado River Basin is divided into the Upper and Lower Basins at the Lee Ferry Colorado River Compact Point (Compact Point) located in northern Arizona. The Upper Basin spans portions of Wyoming, Colorado, New Mexico, Utah and northern Arizona. The Lower Basin covers parts of Nevada, Arizona, California, south-western Utah and western New Mexico. The Colorado River also supplies water to parts of the states of Baja California and Sonora in north-western Mexico.

The Colorado River provides water to almost 40 million people and 4 million to 5.5 million acres of farmland. The Upper Colorado River Basin supplies approximately 90 per cent of the water for the entire Basin, primarily from snowmelt run-off. The Lower Basin is arid, with little tributary run-off reaching the mainstream of the Colorado River except during occasional rain events. The Lower Basin depends upon managed use of the Colorado River System to make its surrounding land habitable and productive. Colorado River water is also delivered to areas that lie outside the Basin's hydrologic boundary, including parts of southern California, the east side of the Front Range in Colorado, the west side of the Wasatch Range in Utah, and parts of northern and central New Mexico. In addition, federally recognized tribes hold a substantial amount of quantified and unquantified federal reserved water rights to the Colorado River and its tributaries.

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[57] UNECE and INBO (2015).

[58] UNECE, *Towards Sustainable Renewable Energy Investment and Deployment: Trade-offs and Opportunities with Water Resources and the Environment*, ECE Energy Series, No. 63 (Geneva, United Nations, 2020).

[59] Paul Sayers and others, *Drought Risk Management: A Strategic Approach* (Paris, UNESCO, 2016).

[60] Dustin E. Garrick and others, "Managing the cascading risks of droughts: institutional adaptation in transboundary river basins", *Earth's Future*, vol. 6 (2018), p. 809–827.

[61] All text constitutes direct quotation from the following United States Government webpages, updated slightly by Government officials: (www.doi.gov/water/owdi.cr.drought/en/index.html; www.drought.gov/news/colorado-river-drought-contingency-planning; www.drought.gov/news/colorado-river-drought-contingency-planning; https://www.usbr.gov/dcp/; www.usbr.gov/newsroom/newsroomold/newsrelease/detail.cfm?RecordID=66103).

The dams, reservoirs, and canals in the Colorado River System provide storage for regional water supply, facilitate water deliveries, provide flood control benefits, improve navigation and generate hydroelectric power. These facilities are operated in coordination with adjacent or nearby water delivery systems that also provide a variety of other economic, cultural and ecological benefits. The Basin's two largest reservoirs, Lake Powell and Lake Mead, hold about 50 million acre-feet of combined storage, which is approximately 83 per cent of the total system storage capacity. This large storage capacity creates a buffer against year-to-year hydrologic variability and longer term drought periods by allowing excess water to be stored during wet years and used during dry years.

Due to year-to-year differences in precipitation and snowmelt, the natural water supply of the Basin is highly variable. Long-term drought such as the Basin has experienced since 2000 reflects natural climate variability coupled with the likely impacts from changing climate. Since most of the Basin's water supply comes from the Upper Basin, drought conditions in the Upper Basin impact on water supply and resources in both the Upper and Lower Basins of the Colorado River.

Since 2000, the Colorado River Basin has experienced the driest 22-year period in more than 100 years of historical natural flows. As a result, the risk of reaching critically low elevations at Lakes Powell and Mead has increased significantly since the drought began. Critically low reservoir levels could affect compliance with the 1922 Colorado River Compact; Lake Powell could drop below the level required to generate hydropower and water shortages in both basins could have a negative impact on the economies, livelihoods and natural resources in both the United States and Mexico.

In the Colorado River Basin, the federal governments, Basin states, Indigenous tribes, local water districts and non-governmental organizations (NGOs) in the United States and Mexico cooperate to develop creative strategies to reduce the impacts of drought and increase reservoir storage at Lake Powell and Lake Mead. Activities related to drought response include a basin-wide system conservation programme and drought contingency planning efforts in both the Upper and Lower Basins through 2020. Water conservation strategies have added approximately 50 feet to Lake Mead's elevation. The implementation of Minutes 319 and 323 to the 1944 United States–Mexico Water Treaty and related binational discussions also underscore the importance of the partnership and continued collaboration between the two countries. Additional planning studies conducted with stakeholders include the 2012 Basin Study and Moving Forward efforts and the Colorado River Basin Ten Tribes Partnership Tribal Water Study. To reduce the risk of Lake Powell and Lake Mead declining to critically low levels, in December 2017, the United States Department of the Interior called on the seven Colorado River Basin states of Wyoming, Colorado, Utah, New Mexico, Arizona, California and Nevada to put drought contingency plans (DCPs) in place before the end of 2018. The Colorado River DCP was submitted to Congress on 19 March 2019. On 16 April 2019, the Colorado River Drought Contingency Plan Authorization Act was signed into law. It requires the Department of the Interior to execute the Colorado River DCP without delay and operate applicable Colorado River System reservoirs accordingly.

The agreements include an Upper Colorado River Basin DCP and a Lower Colorado River Basin DCP. The Upper Basin DCP is designed to: i) protect critical elevations at Lake Powell and help assure continued compliance with the 1922 Colorado River Compact; and ii) authorize storage of conserved water in the Upper Basin that could help establish the foundation for a Demand Management Programme that may be developed in the future. The Lower Basin DCP is designed to: i) require Arizona, California and Nevada to contribute additional water to Lake Mead storage at predetermined elevations; ii) create additional flexibility to incentivize additional voluntary conservation of water to be stored in Lake Mead; and iii) require the Secretary of the Interior to design programmes to create or conserve 100,000 acre-feet or more of system water annually, to benefit Lower Basin system reservoirs, subject to applicable law and availability of appropriations.

In addition to the reductions and other measures to which the Basin states agreed under the DCP, Mexico has also agreed to take additional measures to protect the Colorado River Basin. Under a 2017 agreement, Minute 323 to the 1944 United States–Mexico Water Treaty, Mexico agreed to implement a Binational Water Scarcity Contingency Plan but only after the United States adopted the DCP. Reclamation Commissioner Brenda Burman stated, "This is an historic accomplishment for the Colorado River Basin. Adopting consensus-based DCPs represents the best path toward safeguarding the single most important water resource in the western United States. These agreements represent tremendous collaboration, coordination and compromise from each Basin State, American Indian tribes, and even the nation of Mexico."

As droughts and floods are increasing in certain regions globally, the number of people affected by these phenomena is growing and will further increase in the future. This is due to population growth, but also a result of changing land and water use patterns, such as people moving to marginal lands that are more exposed to the hazards.[62] Drought risks and impacts usually vary within transboundary basins and aquifer areas. Differences exist not only in the timing of rainfall deficits, but also in how run-off is generated and regulated across the basin. Drought affects groundwater resources depending on hydrogeological conditions, and through increased demand and consumption as availability of surface waters diminishes and via lowered seepage and renewal.[63]

Drought and flood risk in transboundary settings may be further understood as the interaction between: i) the *hazard* (i.e. drought or flood); ii) *exposure* to those hazards, i.e. the population, and environmental and socioeconomic assets potentially affected; and iii) *vulnerability*, i.e. local and transboundary water governance capacity to manage impact of the hazard. The exposure to drought will further vary according to the type of water use, distribution of population in rural and urban areas, and environmental assets. Vulnerability to droughts and capacity to manage their impact may also vary significantly across the basin, influenced by water resource development and the distribution of water and shortage risks under transboundary water agreements.[64] Accordingly, transboundary water allocation must look at the distributed risk of drought across a basin, so that the most at-risk parts/areas receive higher or more assured allocations.

Transboundary drought management and water allocation

The multiscale nature of drought requires coordination. In a transboundary context, this means coordinating between riparian States: measures for monitoring and timely data exchange (early warning systems); drought risk mitigation and adaptation strategies; and integrated surface and groundwater management.[65] Water allocation and entitlements are critical in determining what water resources will be available for abstraction and use during drought periods and how those resources will be shared.[66] Groundwater tends to be increasingly relied upon in drought situations, indicating the need to have a good understanding of the availability, renewability and trade-offs associated with groundwater resources. One example of this is heavy groundwater development in proximity to streams, which may reduce base flows in streams (derived from

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[62] UNECE and United Nations Office for Disaster Risk Reduction, *Words into Action Guidelines: Implementation Guide for Addressing Water-related Disasters and Transboundary Cooperation: Integrating Disaster Risk Management with Water Management and Climate Change Adaptation* (New York and Geneva, United Nations, 2018).

[63] Karen Villholth and others, "Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) region", *Hydrogeology Journal*, vol. 21, No. 4 (June 2013), p. 863–885.

[64] Garrick and others, "Managing the cascading risks of droughts" (2018).

[65] See also, for general information, European Commission, Water Scarcity and Droughts Expert Network, "Drought management plan report: including agricultural, drought indicators and climate change aspects", Technical Report, No. 2008 023 (Luxembourg, Office for Official Publications of the European Communities, 2007).

[66] Paul Sayers and others (2016).

groundwater) during dry and drought periods. Proper water accounting is critical for operational water allocation.[67]

Drought often acts as a trigger to, and is easier to identify than, water scarcity as a long-term trend. Drought management thus provides important reflection points for longer term development of management processes and mechanisms,[68] including those related to achieving the SDG targets 6.4 on water-use efficiency, 6.5 on IWRM, 11.5 on disaster risk reduction and 15 on protecting terrestrial ecosystems and combating desertification and land degradation.[69] For legal principles and mechanisms regarding transboundary drought management, see Chapter IV, subsection 6c.

e. Flooding

Impacts of floods in transboundary settings

Flooding can be defined as: overflowing by water of the normal confines of a watercourse or other body of water; and accumulation of drainage water over areas that are not normally submerged.[70] The definition of flood is: (1) Rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate; (2) Relatively high flow as measured by stage height or discharge.[71] Floods are natural climate-driven phenomena that are necessary for the survival and health of many ecosystems. Moreover, some livelihoods, such as floodplain and flood pulse agriculture and fishing, are dependent on floods and there are also related cultural traditions, practices and heritage in some parts of the world.[72] Flood waters are a vital water resource, especially in many arid and semi-arid areas, where they also function as important sources of groundwater recharge.[73] Both regular and exceptional flood events can frequently present a serious hazard to infrastructure and economic assets, health, human lives and the environment.[74]

Risks and impacts of flooding can vary within transboundary basins. It generally depends on the exposure of communities to flooding and the vulnerability of people, their property and infrastructure to flood damage. Probability of damage grows when development activities in river channels and the adjacent floodplains have not accommodated the associated flood risks. The heavier the river channels and floodplains are altered, the lower their resilience to flooding usually is, or, alternatively, the more their impacts are shifted downstream.[75] Both the magnitude and frequency of floods and their associated risks are expected to increase with climate change.[76] Land use changes, i.e. drainage or deforestation, also affect the flood peak height and duration downstream (see Case Study 4 on the Pripyat River Basin and the operation rules for the Vyzhevsky spillway).

The hydromorphology (i.e. shape and cross-sections) of rivers and deltas is constantly changing due to erosion and sedimentation. The changes can also affect a river's flood predictability over time. Heavy floods associated with extreme meteorological events may rapidly change a river's shape and size. Flood protection

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[67] Sood and others (2017).

[68] Anne F. Van Loon, "Hydrological drought explained", *WIREs Water*, vol. 2. No. 4 (July/August 2015), p. 359–392.

[69] See https://sdgs.un.org/goals.

[70] World Meteorological Organization (WMO) and UNESCO, "International glossary of hydrology", 3rd ed., WMO No. 385 (Geneva, WMO, 2012).

[71] Ibid.

[72] See, generally, Fei Yan, "Floods and culture", in *Urban Planning and Water-related Disaster Management: Strategies for Sustainability*, Guangwei Huang and Zhengian Shen, eds. (Cham, Switzerland, Springer International, 2019).

[73] Mark O. Cuthbert and others, "Observed controls on resilience of groundwater to climate variability in sub-Saharan Africa", *Nature*, vol. 572 (2019), p. 230–234.

[74] United Nations, *Transboundary Flood Risk Management: Experiences from the UNECE Region* (New York and Geneva, 2009).

[75] Ibid.

[76] UNESCO WWAP, *The United Nations World Water Development Report* 2020.

or erosion control measures might also affect river morphology.[77] Erosion and sedimentation also impact on the performance of flow regulation infrastructure, which has an important role in both flood protection and implementing water allocation arrangements. In a transboundary context this might have implications on basin agreements and, in turn, on water allocation mechanisms.

Transboundary flood risk management and water allocation

Transboundary flood risk management requires basin-wide monitoring and warning systems. Such systems should focus their measures on parts of the basin where they are most needed and effective and thus enable redistribution of risks and resources. Integrated flood management approaches build on the IWRM approach, risk management principles covering the cycle of preparedness, response, recovery and reconditioning the management system, and also accommodate the beneficial aspects of floods to humans and ecosystems.[78] Similarly to droughts, flood risk management is integral for achieving the aims of SDG 11.5 to significantly reduce the number of people affected by natural disasters.

For transboundary water allocation, floods should generally be approached as exceptional events, the frequency and severity of which are likely to grow in the future. Allocation quotas need to accommodate variability in water availability, but they may also act as flood management measures (see Case Study 8 on the Vuoksi River). It is equally necessary to build monitoring, data exchange, early warning systems and prior notifications of flow releases into allocation agreements between co-riparian States. For legal principles and mechanisms regarding transboundary flood management, see Chapter IV, subsection 6c.

CASE STUDY 4: **Developing climate-adaptable arrangements to manage floods and dry periods in the Pripyat River Basin**

In its upper reach, the Pripyat River flows from Ukraine to southern Belarus. Before reaching Belarus in its natural bed, the Vyzhevsky spillway in Ukraine diverts part of the water from the Pripyat to south-western Belarus to provide water for the Dnieper–Bug Canal. Proper functioning of the longest navigable channel in Belarus depends on water intake via Vyzhevsky spillway, along with other sources. There are important wetlands along the natural riverbed and the diversion channel, making proper balancing of the flow between the two a challenging task.

In 2010, operation rules for the Vyzhevsky spillway were agreed upon between Belarus and Ukraine. The principles of water allocation are based on a bilaterally accepted approach and methodology. Their implementation is monitored on both sides by regional water authorities. Both annually inform the Belarus–Ukraine working group meetings, ensuring the institutional and political stability of the arrangement.

On top of establishing a regime for allocating water to the Dnieper–Bug Canal, the rules regulate activities during floods. Among other issues, the operation rules clarified that Belarus is to deal with maintenance of the headlock of the spillway in the territory of neighbouring Ukraine, resolving longstanding property issues. The rules proved to work well, including during dry periods in 2015 and 2016 when no water was taken from the Pripyat to the Dnieper–Bug Canal. Such cooperative management will become ever more important as climate change intensifies in the Basin.

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[77] L. J. Slater, A. Khouakhi and R. L. Wilby, "River channel conveyance capacity adjusts to modes of climate variability", *Scientific Reports*, vol. 9 (2019), 12619.

[78] United Nations, *Transboundary Flood Risk Management: Experiences from the UNECE Region* (2009).

3. Water Uses and Needs

a. Environmental needs

Ecosystem well-being as a foundation for sustainable water allocation

The health of freshwater ecosystems is the foundation for the sustainability of water resources and the services and benefits derived from water. In modern water allocation arrangements environmental needs are assessed and an environmental reserve is recommended to be set aside before allocating water to other uses.[79] While deciding on environmental requirements in water resources management is ultimately a political process and decision, such decisions should be based on verifiable scientific data. The latest science,[80] as well as the SDGs (notably 6.6, 14, 15),[81] emphasizes that the environment should not be seen as a water-using sector among others, the needs of which may be negotiated, but, rather, that ecosystem well-being must be given high value as it affects all other water uses. The 1992 Convention on Biological Diversity can be used as a general guide for water allocation in this regard insofar as it defines an ecosystem approach relevant to IWRM and distinctly promotes "the restoration and maintenance of biologically diverse ecosystems as a way of improving access to clean drinking water and as a means to eradicate poverty".[82]

Environmental and ecological flows

Environmental needs within water allocation are best described with the concept of environmental flows, often used interchangeably with ecological flows, with both commonly abbreviated to *"e-flows"*. While multiple definitions of the term exist, the most comprehensive recent definition, from The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018), describes environmental flows as "the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being".[83] The concept of ecological flows focuses on ecosystem needs as a part of the overall environmental flow.[84] When properly implemented, environmental flows can achieve multiple benefits, including: helping sustain and generate ecosystem services and livelihoods dependent on them; creating economic and recreational value; preserving rivers; sharing benefits of basin development more equitably; and in general contributing to the sustainable management of rivers.[85]

Environmental flows in transboundary water allocation

Environmental flows have emerged as one of the key frameworks for informed, participatory decision-making in water resources planning to arrive at a balance among extraction, use and conservation of watersheds and their waters.[86] One of the key challenges of environmental flow management is to maintain a sufficient minimum flow of water in rivers and prevent overabstraction during low-flow periods. Periodic high flows

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[79] Speed and others (2013).

[80] Secretariat of the Convention on Biological Diversity, *Global Biodiversity Outlook 5* (Montreal, 2020).

[81] See https://sdgs.un.org/goals.

[82] Secretariat of the Convention on Biological Diversity, *Drinking Water, Biodiversity and Development: A Good Practice Guide* (Montreal, 2010), p. 1. See also, generally, Alistair Rieu-Clarke and Christopher Spray, "Ecosystem services and international water law: towards a more effective determination and implementation of equity?", *Potchefstroom Electronic Law Journal*, vol. 16, No. 2 (2013), p. 12–65.

[83] Arthington and others (2018).

[84] Rafael Sanchez Navarro, "Environmental flows and flow regulation in the Drina River Basin", desk study prepared for UNECE, Geneva, 2019.

[85] Shripad Dharmadhikary, *Environmental Flows in the Context of Transboundary Rivers 2017: Exploring Existing International Best Practices and How They Could be Applied in South Asia* (Berkeley, California, International Rivers, 2017). See also Cate Brown and others, *Good Practice Handbook: Environmental Flows for Hydropower Projects: Guidance for the Private Sector in Emerging Markets* (Washington, D.C., World Bank, 2018).

[86] Sood and others (2017).

are required for maintaining water quality, triggering fish spawning and migration, sediment transport, groundwater recharge and wetland inundation (see Case Study 6 on spring flows from the Dniester River Basin). River ecosystems may also be negatively affected if too much water is released from storage during periods when rivers would naturally experience low flows.[87] As all aspects of the environmental flow regime are potentially important to the environment, ideally, water allocation arrangements should account for natural variability, predictability, seasonal timing and flood magnitude of the given aquatic system and its connections to other systems (e.g. surface and groundwater).

CASE STUDY 5: **Ecological flow and water allocation in the Samur River**

For rational use and protection of the Samur River, a border river between the Russian Federation and Azerbaijan, a bilateral agreement was signed in 2010. Importantly, 30.5 per cent of the water shall be reserved for the ecological flow while the rest is allocated equally between the countries as per Article 3 of the agreement. It is also stated that satisfying the need for water of either country is not allowed at the expense of ecological flow. As some of the groundwaters are hydraulically connected with surface waters of the Samur, the countries have also agreed to ensure the regime of groundwater abstraction, which excludes a decrease in the groundwater level in the Samur River delta.

In transboundary settings, environmental flow assessments provide optimal results when undertaken as a joint exercise considering the river basin in a holistic manner. Assessments should account for interlinkages and interdependencies across political boundaries. Besides national- or State-level stakeholders, local stakeholders directly dependent on and affected by the flow regulations should be consulted.[88] A functional transboundary environmental flow programme requires harmonization of environmental flow methods in the basin, integration of environmental flows in the water planning and allocation and their effective implementation, operational rules (i.e. for reservoirs) and exchange of information.[89] For the necessary knowledge base for the assessment of environmental requirements and assessment methods, see Chapter VII, section 10.

CASE STUDY 6: **Springtime artificial ecological water releases in the Dniester River Basin**

Since the 1980s, springtime artificial ecological water releases have taken place at the Dniester Hydropower Hub to provide water for flora and fauna in the middle and lower stretches of the Dniester River. The Hydropower Hub was constructed in the 1980s to improve flood protection and water availability during low-water periods for Moldova and for Odessa City and oblast in Ukraine, among other reasons. Analysis is still needed to study and address ecological flow needs throughout the year rather than only during the spring season. At the request of the Governments of Moldova and Ukraine, the GEF Dniester Project undertook a study[90] that included development of a simple "calculator" tool that can be used to support operational decision-making when comparing and selecting specific release scenarios depending on the hydrological situation, requirements, limitations and expectations.

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[87] Speed and others (2013).

[88] Dharmadhikary (2017).

[89] Navarro (2019).

[90] Oksana Huliaieva and Nickolai Denisov, *Analysis of the Goals, Limitations and Opportunities for Optimizing the Regime of Spring Ecological Reproductive Releases from the Dniester Reservoir* (Kyiv, Organization for Security and Cooperation in Europe, 2020).

b. Water use sectors and functions

Sectors, functions and in-stream uses

Water allocation has a key role in balancing water availability for different sectors and functions, ideally after the environmental flow requirements have been accounted for. While major differences in sectoral shares exist between countries depending on their socioeconomic structures, agriculture, including inland aquaculture, continues to be the biggest water user globally, constituting 69 per cent of water withdrawals.[91] Industries contribute 19 per cent, including water use in the energy sector, while municipal and domestic uses amount to 12 per cent.[92]

The other main functions or in-stream water uses that depend on known or sustained water levels but do not contribute to water withdrawals per se include navigation, pollution dilution, tourism and recreational uses, cultural uses, freshwater capture fisheries and ecosystem maintenance.[93] For example, Niagara Falls, shared between the United States and Canada, is governed by treaties that allocate fixed quantities of water that are variable depending on the time of year. This is done to ensure that the Falls' aesthetic is preserved during months of heavy tourism, while simultaneously satisfying hydropower requirements of the nearby power generation stations.[94]

Consumptive and non-consumptive uses

An important distinction to be made when assessing water use of different sectors and functions is whether their use is consumptive or not. For consumptive uses, the water withdrawn is effectively removed from the local water body, such as via evapotranspiration in agriculture and evaporation in thermoelectric power generation, or its quality is changed. In non-consumptive uses, water is not withdrawn from (e.g. in-stream water use), or it is returned to, the same water body (sometime after treatment) and may be reused or recycled. Some industrial and domestic water uses, as well as different functions, are non-consumptive by their nature, but with most of them direct reuse of the released or otherwise affected water is typically limited by a change in its quality.[95] A key parameter defining both surface and groundwater availability is the ratio between water consumption and renewable freshwater resources. A consumption rate higher than renewal results in water stress and depletion of the water source over time.

While improving water use efficiency is generally encouraged, it may also reduce return flows, the amount of water seeping into groundwater or available for downstream uses. Disregard for diminished return flows or other interceptions of run-off as a result of afforestation, for example, may result in overestimation of available water resources, their overallocation and overuse. Furthermore, improvements in water use efficiency may not change or may even increase overall water consumption if caps for abstraction are not in place.[96] Allocation arrangements therefore need to account for effects of water use by one user on water use by others, specifying consumption rates of various uses and return flows, including the water quality of the same or different water entitlements.[97]

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[91] Food and Agriculture Organization of the United Nations (FAO), "Aquastat: FAO's global information system on water and agriculture".

[92] Ibid.

[93] Amit Kohli, Karen Frenken and Cecilia Spottorno, "Disambiguation of water use statistics", 23 September 2010 (FAO).

[94] See Treaty Between Canada and the United States of America Concerning the Diversion of the Niagara River, 1950 ("the Niagara Treaty").

[95] Kohli, Frenken and Spottorno (2010).

[96] Chris Perry and Pasquale Steduto, *Does Improved Irrigation Technology Save Water? A Review of the Evidence: Discussion Paper on Irrigation and Sustainable Water Resources Management in the Near East and North Africa* (Cairo, FAO, 2017).

[97] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

Water use in agriculture

Agricultural priorities have traditionally dominated national water allocation arrangements globally. Being afforded such high priority has been due largely to agriculture's direct connection to food security and rural livelihoods. In many countries, agriculture's position has also been challenged by growing water demand from other sectors and uses such as industries and tourism. Agriculture limits availability of water for other uses due to its commonly dominant share of total water use and pollution loading (e.g. excess nutrients, use of pesticides, herbicides and fungicides). Conversely, agricultural practices can add to water availability due to their relative flexibility in accommodating variability (e.g. annual rather than fixed capital costs) and via major return flows. Furthermore, in many regions and in the case of many crops, water demands for agriculture occur at certain periods of the year and may be of limited duration when water availability is low. In years of surplus water availability, agriculture may be best positioned to utilize more abundant allocations, and agricultural land, irrigation and drainage systems may also regulate the excesses in flows.[98] Now and in the future, agricultural water use must be balanced with uses in other sectors, especially in drought conditions.

There is potential for major water savings in agriculture, providing both for the growing needs of other sectors and the need for an increase in food production.[99] Increased water productivity (crop/value per drop) can be achieved, for example, with improvements in water use efficiency (SDG 6.4) (e.g. more efficient irrigation technologies, fertilizer use and soil management) and crop management (e.g. change of crops, crop rotation). These changes are generally supportive of downstream needs when providing improved water availability and water quality (SDG 6.3), but they should also accommodate dependency on previous return flows if improved efficiency leads to their reduction.

CASE STUDY 7: **Allocation for irrigation with monitoring and maintenance systems in the Zarumilla River Basin**

Water stress is a critical characteristic of the Zarumilla River Basin shared between Ecuador and Peru, particularly in the extended dry seasons. It is a relatively dry region between both States with important presence of water-intensive crops such as rice, sugar cane and fruits. The socioeconomic characteristics of this basin demand high volumes of water to satisfy agricultural needs, aquaculture (shrimp farms) and human consumption.

In 1944, the critical water condition forced Ecuador and Peru to cooperate in order to share a water infrastructure channel aimed at assisting irrigation in the border area, sharing costs but also sharing benefits through a simple coordinated water allocation mechanism. The Zarumilla International Water Channel (part of the Zarumilla Basin) was built in 1947. This approach was feasible for the particular context of the Zarumilla because the watercourse acts as a border and, at the same time, agricultural fields surround both sides of the watercourse, creating a common need to share flows.

According to the agreements signed by both countries, the allocation of flows establishes 55 per cent for Ecuador and 45 per cent for Peru. However, when flows are below 1.5 m^3/s (which happens in various months), both countries will take turns to use the flow, for an equal number of days. The agreement also establishes a permanent e-flow of 0.4 m^3/s to maintain ecosystem health in the waterway to the ocean.

The maintenance and cleaning of the Zarumilla channel are performed jointly by the countries in cooperation with subnational governments. Today, channel maintenance is conducted by the countries alternately, with Ecuador responsible for cleaning and paying the infrastructure insurances and associated costs in one year and Peru the next. The monitoring and enforcement of water allocations is overseen

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[98] Speed and others (2013).

[99] FAO, *The State of Food and Agriculture: Overcoming Water Challenges in Agriculture* (Rome, 2020).

by the water user associations of both countries, who have been cooperating for decades in securing the correct use of the waters they rely on (see Chapter VIII, section 3).

Water use in industry and energy production

Industrial water use is typically dependent on sustained quantity and quality of water, whereby sudden reductions in water availability can potentially lead to higher costs and/or production losses. Water quality requirements vary significantly depending on the type of industry, food and beverages and pharmaceuticals exemplifying the highest standards. Besides its growing prioritization for economic reasons, industrial water use may limit water availability for other uses due to point-source pollution. Water use efficiency (SDG 6.4) in industries and energy generation can generally be improved with optimized processes, more efficient technologies and recycling, reuse, reduction or even, where appropriate, replacement of water use with waterless alternatives.[100] Curbing water pollution from industries (SDG 6.3) goes hand in hand with efficiency improvements and provides cost savings and lower water-related risks to business.[101] For further information on complementary approaches on water and energy to transboundary water allocation, see Chapter IV, section 2.

Availability of water in the energy sector is critical for society and gaining increasing international attention as demand for resources mounts and governments continue to struggle to ensure reliable supply to meet sectoral needs.[102] Water shortages may lead to power outages or significant generation losses, with typically widespread impacts on all other sectors and their water use systems. In transboundary water management and allocation contexts, an especially important aspect to consider is flow regulation. The production of hydropower is mainly associated with reservoirs, which, in many cases, have a continuous multipurpose function, such as flood protection, navigation, as a source for consumptive use of water, or recreational water use activities. Since hydropower is commonly generated to meet peak demands, however, hydropeaking may occur and, if not adjusted upon high flows, flooding may be aggravated downstream.

Dams, particularly large-scale hydropower dams, may cause a range of direct or indirect impacts, including: environmental impacts, such as altered fish spawning, biodiversity loss and reduced sediment loads; social impacts, such as loss of livelihood and involuntary resettlement of local communities; and potentially exacerbating climate change impacts.[103] Any such impacts that could cause significant transboundary harm should be addressed in both the planning and operationalization phases, if not already at a stage of strategies and policies (e.g. designation of no-go zones). Measures to address impacts include the placement, size (capacity) and design of individual dams, which need to be subject to environmental impact assessment (EIA), including for transboundary impacts, along with prior notification and consultation. Depending on the outcomes, this may require further negotiation, redesign or searching for alternative solutions. Additionally, it is beneficial for States to seek to agree on an operational regime that reconciles different

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[100] Andrea Rossi, Ricardo Biancalani and Lucie Chocholata, "Change in water-use efficiency over time (SDG indicator 6.4.1): analysis and interpretation of preliminary results in key regions and countries", SDG 6.4 Monitoring Sustainable Use of Water Resources Papers (Rome, FAO, 2019).

[101] CDP, *Cleaning Up Their Act: Are Companies Responding to the Risks and Opportunities Posed by Water Pollution?* (London, CDP Worldwide, 2020).

[102] Diego J. Rodriguez and others, "Thirsty energy", Water Papers, No. 78923 (Washington, D.C., World Bank, 2013).

[103] See, for example, Dominique Égré and Pierre Senécal, "Social impact assessments of large dams throughout the world: lessons learned over two decades", *Impact Assessment and Project Appraisal*, vol. 21, No. 3 (2003), p. 215–224; Marcus W. Beck, Andrea H. Claassen and Peter J. Hundt, "Environmental and livelihood impacts of dams: common lessons across development gradients that challenge sustainability", *International Journal of River Basin Management*, vol. 10, No. 1 (2012), p. 73–92; Zali Fung and others, "Mapping the social impacts of small dams: the case of Thailand's Ing River basin", *AMBIO: A Journal of the Human Environment*, vol. 48, No. 2 (2019), p. 180–191; Bridget R. Deemer and others, "Greenhouse gas emissions from reservoir water surfaces: a new global synthesis", *BioScience*, vol. 66, No. 11 (November 2016), p. 949–964; see, generally, Asit K. Biswas, "Impacts of large dams: issues, opportunities and constraints", in *Impacts of Large Dams: A Global Assessment*, Cecilia Tortajada, Dogan Altinbilek and Asit K. Biswas, eds. (Berlin-Heidelberg, Springer, 2012.)

needs and cascades of dams with different operation regimes. This requires cooperation and potentially joint infrastructure development, which can further facilitate broader benefit-sharing.[104]

CASE STUDY 8: **Vuoksi River hydropower generation and flow levels**

The flow of the Vuoksi River, shared between Finland and the Russian Federation, and levels of the connected Lake Saimaa are governed by two main agreements, the 1989 Vuoksi Discharge Rule and the 1972 Vuoksi Hydropower Agreement. The main aims of these agreements are to ensure the efficient use of four hydropower stations, two on either side of the border, and to manage floods and droughts.

The 1972 Vuoksi Hydropower Agreement governs the daily regulation of streamflow in a way that ensures efficient use of two hydroelectric stations, one on the Finnish side of the border (upstream) and one on the Russian side (downstream). The daily regulation of the streamflow at the Russian "Svetogorsk" hydroelectric stations downstream to the Finnish "Imatra" hydroelectric station upstream must follow certain water flows and upstream water levels detailed in the Agreement. By maintaining these flows, the parties have identified and agreed that this causes the permanent loss of 19,900 MWh per year of electric energy at Imatra and agree that the loss is to be compensated by Russia through annual energy transfer (see also Chapter VI, Case Study 19 re transboundary harm and compensation).

Under the 1989 Vuoksi Discharge Rule, Finland, as an upstream country, must release water from Lake Saimaa in such a manner that the water level of the lake and the flow into the Vuoksi River remain as far as possible within normal limits. Finland must monitor changes in water conditions in the Vuoksi River system, prepare a preliminary appraisal of them and inform the Russian Federation of changes in the normal water release. The normal water limits are + or - 50 cm from the median water level specified in the Discharge Rule. If it becomes apparent that water levels higher or lower than normal are imminent, water releases may be adjusted at the first opportunity so that any damage which may be anticipated can be effectively prevented in time. Every effort must be made to prevent too great a rise in the water level of Lake Saimaa (NN + 76.60 m). At the same time, every effort shall be made to minimize any possible damage to the Vuoksi River. Under this rule, lowering the water level below minimum levels (NN + 75.10 m during the shipping season and NN + 75.00 m at other times) must also be prevented whenever possible. As a result, every effort must be made to maintain a certain velocity of flow (300 m^3 per second).

Domestic water use

While minor in comparison to water use in agriculture, industries and energy production, ensuring water of safe quality for domestic use is of high priority, and where appropriate, of the highest priority, due to its vitality for human health and well-being (see SDG 6.1, 6.2) (see also Chapter V, section 3c).[105] Water use efficiency at homes depends heavily on behavioural choices of households (influenced by climate, cultural traditions, pricing of water services) besides the technologies and systems available.[106]

Water use sectors and functions in transboundary water allocation contexts

At the national and subnational levels, granting water rights and entitlements for different uses and functions is predominantly a matter of national and subnational water governance within a particular jurisdiction (see

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[104] UNECE, *Policy Guidance Note on the Benefits of Transboundary Water Cooperation* (2015).

[105] Both domestic and international water laws recognize the human right to water, and in particular Article 10(2) of the 1997 Watercourses Convention provides that "In the event of a conflict between uses of an international watercourse, it shall be resolved with reference to articles 5 to 7, *with special regard being given to the requirements of vital human needs*" [emphasis added].

[106] FAO and UN Water, *Progress on Water-use Efficiency: Global Baseline for SDG Indicator 6.4.1* (Rome, 2018).

Case Study 18 on the Murray–Darling Basin), which should, however, keep in mind governance at the basin level.[107] In fact, while national needs inform negotiations on transboundary water allocation, they are best coordinated as part of basin-wide planning, integrating consideration of future scenarios. These processes could benefit from the possibilities regarding cost- and benefit-sharing and further opportunities from applying the water-energy-food-ecosystem nexus approach (see Chapter IV).

4. Impacts on Allocable Water

a. Water management infrastructure

Infrastructure as an enabling and limiting factor in water allocation

Water management infrastructure sets the physical basis for, and constraints on, how allocable water can be used. Freshwater infrastructure traditionally includes:

- dams for hydropower, flow regulation, storage and water withdrawal;
- reservoirs;
- pumping stations for rivers and aquifers for supply of water;
- irrigation systems;
- water purification and wastewater treatment plants and water and wastewater networks, and outlets returning wastewater to these systems;
- dredging, channelization or straightening of rivers for navigation;
- basin transfer pipelines and canals;
- natural and human-made ponds and swamps;
- monitoring systems and networks.[108]

Historically, growing demand for water was typically first met with infrastructure development, increasing access to available water.[109] Investing in upkeep, repairs and modernization of existing infrastructure (e.g. canal networks) has significant potential to improve water efficiency and various demand management means overall. It may also reduce the need to spend on expanding new development for additional supply. Allocation planning is therefore useful in the development and operation of certain infrastructure and related water uses that pertain to the transboundary allocation of water resources.

Past infrastructure choices can limit existing and future allocation options. Large dams, water transfers and large-scale irrigation systems typically have profound impact on flow regulation, groundwater, the environment and downstream water uses. Poorly maintained large-scale infrastructure can lead to major transboundary risks of losses or water wastage, exacerbating water scarcity, water contamination and accidents such as dams breaks and flash floods. Inadequate infrastructure further reduces adaptive capacity to respond to drought and floods and longer-term changes in water availability and variability.[110] Disparities in infrastructure between/among States sharing transboundary water resources may also create unequal water utilization opportunities. Existing and planned transboundary infrastructure systems must carefully assess how to be equitable, avoid harm and evaluate ways to minimize transboundary environmental impacts (e.g. fish passages or outlets for e-flows on hydropower dams) and socioeconomic impacts.[111]

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[107] See, generally, Garrick, *Water Allocation in Rivers under Pressure* (2015).

[108] Alternative water sources such as harvested rainwater or desalinated water have their own infrastructure, which in a larger scale may be linked to main networks and systems.

[109] McCracken and others, "Typology of Transboundary Water Allocation" (forthcoming).

[110] UNESCO WWAP, *Managing Water under Uncertainty and Risk*, United Nations World Water Development Report 4, vol. 1 (Paris, UNESCO, 2012).

[111] UNECE, *Policy Guidance Note on the Benefits of Transboundary Water Cooperation* (2015).

CASE STUDY 9: Joint management of water infrastructure in the Chu–Talas River Basin

In the Soviet period up to 1991, intra-State principles and conditions were used to allocate water resources of the Chu and Talas River Basins between the Kazakh and Kyrgyz Soviet Socialist Republics. In 2000, Kazakhstan and Kyrgyzstan signed the Agreement on the Use of Water Management Facilities of Intergovernmental Status on the Rivers Chu and Talas. The Agreement covers six water infrastructure objects in upstream Kyrgyzstan (reservoirs, canals, waterworks).

According to the Agreement, downstream beneficiary Kazakhstan reimburses Kyrgyzstan for the operational costs of maintenance, repair, overhaul and reconstruction of inter-State water management facilities in proportion to the volume of water it receives. For each year, the required amount of funds is agreed between the parties. Kazakhstan finances most of its costs by conducting maintenance and construction works itself. A standing bilateral commission on an equal footing with the permanent secretariat sets an operational schedule and defines required expenditures. There is a desire to add further water infrastructure objects for joint management and to clarify the status and financing of the permanent secretariat.

Kyrgyzstan used the Agreement as a model when signing a similar agreement with its other downstream neighbour, Uzbekistan, in 2017 for joint management of the Orto–Tokoi (Kasansay) water reservoir.

Developing sustainable infrastructure for water allocation

The larger the infrastructure, the more careful its selection, size and choice of location needs to be and the more comprehensively co-riparian States and all other key stakeholders should be engaged in its development. Appropriate infrastructure choices, including size and location, may contribute to fairer water allocation between parties, avoid harm, provide more value to users and maintain a healthy environment.[112] Large-scale infrastructure is typically expensive to build and expected to last and serve for decades. In order to ensure its functionality in changing circumstances (e.g. impacts of climate change, structural changes in the economy, technological innovations), infrastructure needs to pass sensitivity and risk analyses and environmental and social impact assessments in different simulations and scenarios.

Nature-based solutions to water allocation infrastructure rarely have negative transboundary impacts, while they simultaneously help to meet environmental requirements. Nature-based solutions may include those for managing water availability (e.g. natural wetland forests and wetlands' improved soil and vegetation management), water quality (e.g. forest, wetlands, grasslands) and water-related risks, variability and change (e.g. flood plains, surface and subsurface water storage and managed aquifer recharge).[113]

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[112] Ramsar Convention Secretariat, *Water Allocation and Management: Guidelines for the Allocation and Management of Water for Maintaining the Ecological Functions of Wetlands*, Ramsar Handbooks for the Wise Use of Wetlands, 4th ed., vol. 10 (Gland, Switzerland, 2010); Karen G. Villholth and Andrew Ross, *Groundwater-Based Natural Infrastructure (GBNI)* (n.p., n.d.), available at https://gripp.iwmi.org/wp-content/uploads/sites/2/2018/08/GBNI_Intro.pdf; Groundwater Solutions Initiative for Policy and Practice (GRIPP), "Groundwater-based natural infrastructure: GBNI" (n.d.), available at https://gripp.iwmi.org/natural-infrastructure/.

[113] UNESCO WWAP, *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water* (Paris, 2018).

CASE STUDY 10: Value of investing in nature-based solutions and implementing measures where they make a difference, even across borders: flood protection in the Rhine River Basin

Under the Interreg Rijn Maas (IRMA) programme, the Netherlands contributed some €5 million to the construction of the Bislicher Insel retention area in Germany. The retention measure was included in the International Action Plan on Floods on the Rhine adopted by ministers of the Rhine riparian countries in 1998. The measure consisted of putting back a band embankment and lowering the old band embankment in parts, so that the water can flow into an old arm of the Rhine in both summer and winter when a certain water level is exceeded, hence reducing flood waves. With this solidary co-financing, the Netherlands contributed to the realization of the whole package of measures implemented in the Action Plan, aimed at reducing extreme water levels, with a positive effect for the country.[114]

Water scarcity as a central challenge for sustainable water allocation

Water scarcity occurs when demand for freshwater exceeds supply.[115] It seriously affects the functioning of societies and undermines possibilities for sustainable development. Population growth, urbanization and changing consumption patterns, increased demand from irrigated agriculture, industry and hydropower, as well as inadequate water management, all contribute towards scarcity of water resources. Water scarcity may compromise water supply and sanitation services and have negative impacts on human health. It may also threaten food security and limit economic growth because of declining agricultural production, while the environment suffers from reduction in environmental flows. Water scarcity may lead to conflict within and across countries and exacerbate forced migration.[116] It is estimated that, in arid and semi-arid regions, climate-change-induced water scarcity may displace up to 700 million people by 2030.[117]

Climate change further accelerates the effects of scarcity. The results can be an increase in the frequency and intensity of droughts and floods, changes in precipitation patterns, higher surface water evaporation and depletion of glacial and surface water sources (see subsection 2c above on the cross-cutting impacts of climate change). In transboundary contexts, water uses in one riparian State can impact or exacerbate water scarcity in another. Water scarcity sets absolute or relative limits to allocable water. Water scarcity thus forms a central challenge for sustainable allocation of transboundary water resources as "ever-increasing withdrawals of water from the world's freshwater ecosystems are creating new threats as water stress leads to pervasive, catchment-scale reductions in ecosystem functions. Catchment-scale challenges such as these, with widespread social, economic and environmental consequences, can no longer be addressed by local engagement at a limited number of sites, but require broader solutions: effective water allocation mechanisms are required that match the scale of the problem."[118]

Definitions and aspects of water scarcity

Water scarcity has multiple definitions and aspects. Physical water scarcity arises out of the low availability and shortage of water resources, while social water scarcity is caused by unbalanced power relations,

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[114] An evaluation of all retention measures implemented along the Rhine can be found in International Commission for the Protection of the Rhine (ICPR), "200. and 199.: Balance on the implementation of the Action Plan on Floods between 1995 and 2010". 26 July 2012. See also Interreg Rhein-Meuse Activities (IRMA), "Germany". Available at www.irma-programme.org/b_projects/list_germany.htm.

[115] FAO, "Coping with water scarcity: an action framework for agriculture and food security", FAO Water Reports, No. 38 (Rome, 2009).

[116] UNECE and INBO (2015).

[117] Elizabeth Hameeteman, *Future Water (In)Security: Facts, Figures, and Predictions* (Brussels, Global Water Institute, 2013).

[118] Le Quesne, Pegram and Von Der Heyden (2007), p. 8.

poverty and related inequalities.[119] Another important aspect of water scarcity is economic water scarcity. This occurs due to lack of investment in water infrastructure or a lack of human capacity to satisfy the demand for water.[120] Scarcity of capacity (organizational scarcity) and scarcity of accountability are further measures of water scarcity.[121] It is useful to make a distinction between absolute and perceived scarcity. Absolute scarcity exists when there is no affordable source of additional water within a given area, or where the costs of additional water supplies exceed the benefits of their provision. Even scarcity that is perceived as absolute may be relative and related more to structural problems regarding water supply or distribution. These perceptions therefore need to be addressed before there is actual "measurable" scarcity.[122]

BOX 5: "WATER STRESS VS "WATER SCARCITY"

Water stress is commonly used to mean scarcity in situations where water use exceeds natural renewal capacity of water resources. SDG indicator 6.4.2 defines the level of water stress as freshwater withdrawal as a proportion of available freshwater resources, where over 70 per cent is serious water stress.

Source: Food and Agriculture Organization of the United Nations (FAO) and UN Water, *Progress on Level of Water Stress: Global Baseline for SDG 6 Indicator 6.4.2 2018*, IMI-SDG 6 SDG 6 Progress Reports (Rome, 2018).

A good summary of when and how allocation approaches may typically be employed to address water scarcity that has often led to water stress is provided by WWF: "There typically comes a point, however, at which engineering solutions will no longer suffice to meet increased demand, or are considered to be economically, socially or environmentally undesirable. When this happens, over-abstraction from the ecosystem leads to water stress, with serious negative impacts on social and economic development and the deteriorating health of aquatic ecosystems. Where there is no further water available for use, catchments are referred to as 'closed'. When such water stress is reached, a new and more sophisticated approach to water management is required. Rather than an engineering approach, these approaches seek to restore river flow through a multi-disciplinary and multi-stakeholder process of managing water withdrawal. Effective water allocation mechanisms need to be developed that manage the use of the scarce resource. In more prudent cases, such allocation systems may be introduced before catchments experience major water stress, but often a crisis is required to inspire reform."[123]

Combating water scarcity in transboundary water allocation

The different aspects of water scarcity highlight important challenges for transboundary water resources management. Four billion people, nearly half the world's population, experience water scarcity at least one month a year and half a billion live in conditions of permanent water scarcity.[124] Hence, the transboundary dimension of water scarcity has attracted more international attention. For example, SDG target 6.4 is to substantially reduce the number of people suffering from water scarcity, while SDG target 6.5 is to implement integrated water resources management at all levels, including through transboundary water

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[119] M. Falkenmark and others, "On the verge of a new water scarcity: a call for good governance and human ingenuity", SIWI Policy Brief (Stockholm, Stockholm International Water Institute, 2007).

[120] David Molden, Charlotte de Fraiture and Frank Rijsberman, "Water scarcity: the food factor", *Issues in Science and Technology*, vol. 23, No. 4 (Summer 2007), p. 39–48.

[121] World Bank, *Making the Most of Scarcity: Accountability for Better Water Management Results in the Middle East and North Africa* (Washington, D.C., 2007).

[122] UNESCO WWAP, *Managing Water under Uncertainty and Risk*, United Nations World Water Development Report 4, vol. 1 (2012).

[123] Le Quesne, Pegram and Von Der Heyden (2007), p. 8.

[124] Mesfin M. Mekonnen and Arjen Y. Hoekstra, "Four billion people facing severe water scarcity", *Science Advances*, vol. 2, No. 2 (2016), e1500323.

cooperation. Development of new allocation agreements and other arrangements, and renegotiation of existing ones, should in turn be aligned with these and other SDG targets.

Recognition that water scarcity conditions are likely to become more severe and frequent in the future supports reconsideration of certain prevailing approaches to water allocation in many river basins and aquifers around the world. Combating water scarcity requires reconsidering traditional supply management strategies such as increasing capacity of water infrastructure.[125] The focus needs to be shifted to demand management options such as increasing water use efficiency and water productivity. For successful integration of mitigation and adaptation strategies addressing water scarcity within transboundary allocation frameworks, the drivers and impacts of water scarcity need to be identified and understood in each context. Therefore, in water-scarce regions especially, "countries need to focus on the efficient use of all water sources (groundwater, surface water and rainfall) and on water allocation strategies that maximize the economic and social returns to limited water resources, and at the same time enhance the water productivity of all sectors. In this endeavour, there needs to be a special focus on issues relating to equity in access to water and on the social impacts of water allocation policies."[126]

b. Water quality

Water quality as a factor of water availability

Water availability is not only a question of quantity, as deteriorating quality limits water uses for multiple purposes. Changes in volume and timing of flow as a result of withdrawals and discharges or dam storage equally affect water quality by altering the amount of dissolved oxygen, channel erosion, compound condensations and suspensions, and turbidity, and, in some cases, temperature. Water quality varies naturally along rivers and aquifers, influenced by altitude, geology, in-stream habitat, wetlands and floodplain connectivity, as well as over time due to changes in climate and flow regime.[127] Freshwater ecosystems have major water-quality-managing functions, but they are also heavily affected by human impact. Water quantity and quality, combined with ecosystem health, should therefore be approached as equally important aspects in water availability and any related allocation measures.

Drivers and impacts of water quality degradation

Water quality degradation is a sum of alterations of flow regimes, ecosystems, climate change and polluting discharges. Over 80 per cent of the world's wastewater, including sewage, agricultural run-off and discharges from industry, is estimated to be released into the environment without treatment.[128] Both point-source and diffuse pollution degrade water quality. Point-source pollution originates from pipes, outlets and ditches of sewage treatment plants, industrial sites and livestock operations. It causes the worst water quality impacts during low flows when water bodies have reduced dilution capacity. Storm and flood events can also cause overflows from sewerage systems. Diffuse pollution refers to nutrient run-off and leaching from agriculture and forestry, atmospheric deposition of nitrogen oxides from energy and transport emissions, and run-off of petroleum hydrocarbons and heavy metals from urban surfaces to surface and groundwaters. It continues to be a major problem, even in regions where point-source pollution has been effectively curbed.[129] In water bodies, polluting solutes and particles such as pathogens, organic matter, salt, hazardous chemicals

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[125] David Molden, "Scarcity of water or scarcity of management?", *International Journal of Water Resources Development*, vol. 36, No. 2–3 (2019), p. 258–268.

[126] UN-Water, *Coping with Water Scarcity: A Strategic Issue and Priority for System-wide Action* (Geneva, 2006), p. 2.

[127] Christer Nilsson and Birgitta Malm Renöfält, "Linking flow regime and water quality in rivers: a challenge to adaptive catchment management", *Ecology and Society*, vol. 13, no. 2 (2008), 18.

[128] United Nations WWAP, *The United Nations World Water Development Report 2017: Wastewater: The Untapped Resource* (Paris, UNESCO, 2017).

[129] OECD, *Diffuse Pollution, Degraded Waters: Emerging Policy Solutions* (Paris, 2017).

and materials, pharmaceutical residues, microplastic and endocrine-disrupting chemicals are transported downstream or infiltrate into aquifers, making pollution also a transboundary problem.[130]

Water quality in transboundary water allocation

Deteriorating water quality has been a driver for several recent allocation reforms.[131] It decreases the available resource pool and the need for treatment increases the costs of water use. Water quality degradation reduces the value derived from in-stream uses including ecosystem functioning, fisheries and recreational uses.[132] However, in many transboundary river basins, water quality data are not collected or exchanged by riparian States in a uniform manner, if at all.[133] The number of measured water quality parameters varies by State and comparability is limited by the temporal and spatial representativeness of data. Moreover, national water quality monitoring may be the responsibility of several different agencies.

CASE STUDY 11: **Addressing water quality in transboundary water allocation for the Great Lakes**

The Great Lakes and especially Lake Erie are experiencing severe blue-green algal blooms. The source of the nutrient pollution is tributaries within the United States and Canada. For this and other reasons, the Great Lakes Water Quality Agreement (GLWQA) between the Governments of Canada and the United States was amended in 2012. The GLWQA entered into force in 1978, with amendments in 1983, 1987 and 2012. The GLWQA is implemented by the parties to the Agreement. Article VII of the GLWQA contains a standing reference to the International Joint Commission (IJC). The GLWQA tasks the IJC with a number of responsibilities, including the review of progress in achieving the general and specific objectives of the Agreement and reporting on any problem of water quality of the Great Lakes. Under the GLWQA, the two federal governments monitor and conduct research on water quality.

Under the GLWQA, the IJC has two very effective Great Lakes Advisory Boards. The binational Great Lakes Water Quality Board (WQB) is a very active and progressive board consisting of 28 members, 14 from each country. Half its members represent government agencies and the other half represent basin users and local and tribal governments. It is a unique binational group of experts from all sectors—government, NGOs, academic institutions, etc. The binational Great Lakes Science Advisory Board consists of two committees, the Research Coordination Committee (RCC) and the Science Priority Committee (SPC). Members of the RCC consist primarily of the government agencies responsible for monitoring, research and regulation of the Great Lakes. The SPC consists primarily of university researchers. The SPC focuses on research and data management issues. The WQB focuses on policy.

The worst algal bloom ever experienced on Lake Erie occurred in 2011, prompting the IJC to make binational investigation into the science and opportunities for action by governments to reduce algal-bloom-causing pollution a priority.[134] Daily water quality and river flow monitoring data at key locations were incorporated into appropriate water quality models (e.g. binational SPAtially Referenced Regression

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[130] United Nations Environment Programme (UNEP), *A Snapshot of the World's Water Quality: Towards a Global Assessment* (Nairobi, Kenya, 2016).

[131] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

[132] Ibid.

[133] United Nations Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Working Group on Monitoring and Assessment, Fifteenth meeting, Geneva, 6 December 2019,"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)" (ECE/MP.WAT/WG.2/2019/INF.1).

[134] International Joint Commission (IJC), *A Balanced Diet for Lake Erie: Reducing Phosphorus Loadings and Harmful Algal Blooms: A Report of the Lake Erie Ecosystem Priority* (Washington, D.C., 2014), p. 2.

On Watershed attributes (SPARROW) modelling) to determine loading of phosphorous and nitrogen amounts into Lake Erie and the originating sources of the pollution. The loading numbers were then used to calculate target reduction concentrations in shore and deep lake regions of Lake Erie that would be needed to reduce or eliminate severe algal blooms, as documented in a 2014 Report of the Lake Erie Ecosystem Priority.[135]

The GLWQA requires the IJC to evaluate, every three years, how well the Canadian and United States Governments are meeting the general and specific objectives of the Agreement. Following publication of the State of the Great Lakes Report in 2016, and after extensive public engagement and review of the report, the IJC prepared its first Triennial Assessment of Progress Report on Great Lakes Water Quality in November 2017. The report provides advice and recommendations to assist the United States and Canadian Governments to better meet the general and specific objectives of the GLWQA. The IJC, its Great Lakes Regional Office and Water Policy and Science Advisory Boards are continually refining and updating their analyses to better determine the sources of nutrient pollution and additional mitigation strategies. The federal governments have a responsibility to address nutrient pollution in the Great Lakes consistent with the objectives of the GLWQA.

Addressing water quality issues in transboundary water allocation demands both national and transboundary coordination. Agreeing on acceptable water quality levels should be informed by desired uses for the given water source, and international and national environmental, chemical and health standards, as described in Chapter VII. Cross-sectoral interdependencies should also be addressed, as water quality objectives of an allocation regime may be undermined by incentives in other sectors that encourage pollution.[136] It should also be taken into account that reaching acceptable water quality levels for environmental requirements and human and sectoral needs may require dilution of flows or reservoir management that reduces the total volume of allocable water for all.[137]

c. Ecosystem degradation

The dual linkage of ecosystems degradation to water allocation

Ecosystem degradation is linked to water allocation in two major, interrelated ways. First, healthy ecosystems typically help to maintain overall availability of water, while, conversely, ecosystem degradation reduces it. Second, unsustainable water allocation and water use regimes have a negative impact on freshwater ecosystems, other ecosystems dependent on them and their biodiversity.

In terms of the first linkage, changes in upstream water use in different sectors and for different functions is the dominant external factor influencing the status of the water resources situation downstream. Notwithstanding, the status of ecosystems also affects the quantity, quality and variability of allocable water. Land ecosystems, especially vegetation, play a key role in regulating evapotranspiration and run-off from land. Vegetation typically supports water availability but, in some cases, removal of forests and alien species, for example, may also release more water to streams.[138] As surface and groundwater systems are connected, plant cover may also have a significant impact on groundwater recharge, which, when reduced, may lead to reduction or drying of rivers in low-flow seasons. Furthermore, freshwater ecosystems have multiple functions in flow and water quality regulation, as well as an important role in many other ecosystem services, ranging from food production, including freshwater fisheries, to recreational and cultural values.

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[135] IJC (2014).

[136] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

[137] Speed and others (2013).

[138] D. C. Le Maitre and others, "Invasive alien trees and water resources in South Africa: case studies of the costs and benefits of management", *Forest Ecology and Management*, vol. 160, No. 1–3 (2002), p. 143–159.

In terms of the second linkage, multiple stressors are involved in having negative impacts on freshwater ecosystems. Changes to river flow regimes and connectivity as a result of water withdrawals and dam construction, water pollution and the general undervaluation of aquatic ecosystems and ecosystem services have contributed to the loss of over 80 per cent of freshwater species populations since the 1970s, with climate change further exacerbating the situation.[139] Loss of biodiversity fundamentally weakens the balance and future resilience of the ecosystems. In turn, there are widespread impacts on both society and the environment through the weakening of the provisioning, regulatory, cultural and habitat-supporting services healthy freshwater ecosystems provide. These realizations have resulted in water allocation frameworks that increasingly prioritize the needs of ecosystems.

Meeting minimum requirements for ecosystem well-being

Natural freshwater ecosystems have evolved to thrive in dynamic hydrological conditions. In almost all contexts, variations in flows and water levels are essential for freshwater species and for ecosystem functions such as sediment transport and fisheries. However, people need water too. In many contexts, the question of meeting ecosystem requirements is less about how to maintain pristine ecosystems and more about understanding how to maintain essential aspects of flow variation even while using water for human social and economic purposes.[140] Environmental flow assessment tools and approaches focus on providing answers to this question (see also Chapter III, subsection 3a; Chapter VII, section 5).[141]

While environmental flow assessment is underpinned by science, decisions about how much water to take from an ecosystem for human use are ultimately social and political in nature. It is crucial that such decisions are made with an understanding that maintaining healthy freshwater ecosystems is not in competition with human water uses; rather, safeguarding or restoring key aspects of ecosystem functioning, such as downstream water supply, freshwater fisheries or sediment transport to low-lying delta regions are strategically important.[142] Thus, ecosystem health should be a foundation of water allocation in a transboundary context as it is crucial for the long-term sustainability of the world's shared freshwater sources.

CASE STUDY 12: **Identifying ecologically sustainable levels of take: an intracountry, cross-border example from the Murray–Darling River, Australia**

The Commonwealth Water Act governing the cross-border Murray–Darling River in Australia requires the Basin Plan to identify sustainable diversion limits (SDLs) for the basin. The SDLs aim to provide an ecologically sustainable level of take at which "key environmental assets and key ecosystem functions" are not compromised. The SDLs define how much surface and groundwater can be extracted for urban water supply, irrigation and other economic activities. The SDL is set for the entire basin and is being set for each subregion (each major river valley) and each groundwater management unit. The basin-wide surface water SDL is set at 10,873 gigalitres per year (GL/y) on a long-term average. A basin-wide long-term average limit of 3,472 GL/y has also been set on groundwater use. To meet the requirements of the SDLs, the Australian Government has been "recovering" water through a combination of water buy-backs and efficiency projects. The basin-wide water recovery target is 2,075 GL/y.

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[139] WWF, *Living Planet Report 2020: Bending the Curve of Biodiversity Loss*, Rosamunde Almond, Monique Grooten and Tanya Petersen, eds. (Gland, Switzerland, 2020).

[140] Speed and others (2013).

[141] Avril C. Horne and others, eds., *Water for the Environment: From Policy and Science to Implementation and Management* (London, United Kingdom, Academic Press, 2017).

[142] Arthington and others (2018).

Preventing ecosystem degradation in transboundary water allocation

Preventing ecosystems degradation has been the main driver for national water allocation reforms in past years.[143] At the transboundary level, ecosystem protection is gradually gaining recognition but requires enhanced cooperative and coordinated efforts. SDG target 6.6 is to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes, by 2020.[144] As this target was not met in the originally intended timeframe and, instead, there is evidence of accelerating negative consequences for both humans and the environment,[145] conservation efforts in the coming years need to respond to growing challenges. New and revised transboundary allocation arrangements and environmental requirements should be assessed and an environmental reserve be set aside before allocating water to other uses (see also Chapter III, sections 1 and 3a; Chapter VII, section 5).

5. Balancing Different Water Uses and Needs

a. Considering historical, current and future uses

Development trajectories of water use

Water use and water allocation has a strong temporal dimension across years and even decades. While water allocation typically focuses on current and (short-term) future water uses, it builds on historical use and development, and should also consider longer-term needs. Consideration of this temporal dimension thus links to the broader view on water and its role in the development of societies, including linkages to food and energy security, as well as the environment. The temporal dimension of water allocation in this regard can be considered through three main trends, or development trajectories: changes in the total water use of a society; comparative changes in the water use between sectors and functions; and changes in water availability due to changing climate and other alterations in the hydrological system. The first two changes can be considered as socioeconomic trajectories that drive water use and which are discussed in this section, while the third is a physical, though human-influenced, trajectory, discussed in sections 1 and 2 of this chapter.

CASE STUDY 13: **Allocation lessons from Australia's governance of intracountry cross-border rivers**

The Murray–Darling Basin (MDB) covers nearly 1 million km^2 of south-eastern Australia. It contains the largest and most complex river system in Australia, with 77,000 km of rivers, many of which are connected. The MDB includes 16 internationally significant wetlands, 35 endangered species and 98 different species of waterbirds. Indigenous peoples have lived in what we now call the MDB for more than 50,000 years and the Basin contains many sacred and spiritually significant sites (see Case Study 18 on Indigenous cultural flows). The MDB has been the site of most Australian intracountry, cross-border water governance experiences, with six governments involved: the federal (Commonwealth) government and those of four states and the Australian Capital Territory.

For about 160 years there have been agreements and plans about how much water can be used from the River Murray and the Basin as a whole. Over the decades more and more water was being extracted. The health of the Murray–Darling system was in decline. The water was overallocated. In 1995 the MDB cap on surface water diversions was introduced, and thereafter annual auditing of compliance with the cap began. It became obvious that further significant changes were needed to the water law, water allocation and water use practices. A devastating drought from 1997 to 2009 catalysed further community

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[143] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

[144] See https://sdgs.un.org/goals/goal6.

[145] WWF (2020).

and political action. This led to a National Plan for Water Security in 2007 and the Commonwealth Water Act (2007). Australia's Water Act is an ambitious piece of legislation that seeks to return water allocations in the MDB to sustainable levels and to coordinate planning and decision-making at the Basin level.

The Act established the Murray–Darling Basin Authority (MDBA), which was given responsibility to: prepare, implement, and review an integrated Basin Plan; operate the River Murray system and efficiently deliver water; measure, monitor and record the quality and quantity of the Basin's water resources; support research; advise the Minister; provide water information to facilitate water trading; and engage and educate the community. The MDBA is responsible for assessing and monitoring Basin state compliance with sustainable diversion limits (SDLs) by towns, communities, industry and farmers. Limits are being set for 29 surface water areas and 80 groundwater areas across the Basin.

The aim of the Basin Plan is to bring the Basin back to good health, while continuing to support farming and other industries for the benefit of the Australian community. It took five years to develop and agree to a plan to manage the Basin as a whole, connected system. For surface water, the Basin Plan requires, on average, a reduction of 2,075 GL of water used for consumption annually across the Basin.

Underpinning the Basin Plan, under preparation, are 33 subbasin water resource plans (WRPs) for surface water and groundwater. These will be legally binding. WRPs must contain: evidence of compliance with SDLs and water trade rules; protection of water for the environment, water quality and salinity objectives; Indigenous objectives and outcomes for values and uses; measuring and monitoring protocols; and arrangements for extreme weather events.

The Murray–Darling Basin Plan, in place since 2012, and backed by $A 13 billion, is one of Australia's most scrutinized pieces of public policy. Since 2012, the overall average water take is down from ~14,000 GL/y to ~11,000 GL/y. Water extractions in the Basin are capped (now to a lower level than previously) and new enterprises can only be established if they purchase existing water entitlements from others. There is no net additional water extraction as a result of such trades.

Problems remain, however, including establishment of accurate water accounting and effective compliance regimes, ecosystem health (as evidenced by fish kills in the summer of 2019), only a tiny volume of surface water holdings being in the hands of Indigenous entities, and maintaining community support and interjurisdictional political buy-in. These are all areas recognized as requiring further attention and improvement. Water entitlements yielding an average of 2,000 GL/y have been acquired for the environment by the federal government, via a combination of government buy-backs and infrastructure modernization. There is an additional ~1,000 GL/y of environmental water. This is a substantial transfer of water from the consumptive pool. It is the largest redirection of water to the environment in any large river basin in the world. The Commonwealth Environmental Water Holder (CEWH, created by the Water Act (2007)), in concert with relevant state government agencies, now routinely and competently delivers these secure water entitlements. Over the past four years, Commonwealth and other environmental water has been used in more than 750 planned watering events to improve the health of rivers and wetlands.

In September 2020, the MDBA has committed to a new range of initiatives to further boost transparency and collaboration. These include: increasing communications about river operations; using new engagement methods tailored to suit local communities; boosting the diversity of MDBA consultative committees, including the addition of Indigenous members; and splitting out the MDBA compliance role to a separate statutory authority.

In conclusion, years of overallocation degraded the ecosystem and climate change is making the recovery task even harder. Climate change projections indicate a small increase in total rainfall in the northern Basin is likely; however, decreasing winter and spring rainfall is consistently predicted for the southern Basin. However, of the many large river basins in the world grappling with water scarcity and conflict between users, the Murray–Darling Basin is one with a strong rules-based order, including clearly defined water entitlements, a cap on extractions, a large environmental water reserve, substantial (but imperfect) transparency and a systematic audit process. For these reasons, when it comes to the complicated business of sharing water among competing interests, basin managers from around the world look to Australia to observe a functioning example of work in progress.

The first development trajectory of total water use has demonstrated a strong upward trend globally over the past 50 years, with water use in all key water-using sectors increasing dramatically.[146] Irrigated land area, abstraction of groundwater, reservoir and hydropower capacity, as well as water use for industrial and domestic uses, have all grown significantly in almost all countries and river basins globally, yet regional differences exist. For example, total withdrawals are now decreasing, on average, in OECD countries.[147] This is partly a result of heightened scarcity, deteriorated water quality and heightened environmental degradation, and partly due to efficiency improvements and lower than expected demand in specific water use sectors. Overestimating demand has led to hugely oversized infrastructure and major costs. Global water withdrawals have been projected to further grow by 55 per cent from 2000 to 2050, as a result of increasing demands from manufacturing (400 per cent), thermal electricity generation (140 per cent) and domestic use (130 percent).[148] While population growth and increasing production and consumption require more water, the potential for efficiency improvements and demand management measures should not be neglected to avoid oversized allocations.

The second development trajectory considers comparative changes in water use between sectors and functions. It may differ greatly, even within an individual river basin, both temporarily (e.g. between different decades and seasonally) and spatially (e.g. between different countries and/or their regions). This trajectory relies strongly on existing policies, as the changes occur through decisions and activities that can increase and decrease both the comparative and actual water use of different sectors and functions. Examples of structural changes on this trajectory include shifts to more water-efficient technologies (e.g. as directed by best available techniques (BAT), less water-intensive crops (e.g. shifting from cotton cultivation to cereals), alternative power generation technologies that are less water intensive, or prioritizing higher economic value and less water-intensive sectors (e.g. tourism and recreation over water-intensive agriculture, where appropriate).

Understanding water use in transboundary settings over time

Different approaches can be applied to understand how water use changes over time in a transboundary river basin or aquifer. One option is to make use of the concept of basin closure or "closed" basins. Basin closure indicates the stage when the majority of water resources within a basin are allocated for various water uses and little to no water from the natural flow and sources remains to be further used and allocated.[149] Three general phases are linked to the concept of basin closure—*development, utilization* and *allocation*:

- In the development phase, water may be abundantly available and water infrastructure is developed to access the resources;
- In the utilization phase, the focus moves from infrastructure construction to improved water management, typically when water availability starts to become constrained;

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[146] M. Kummu and others, "Is physical water scarcity a new phenomenon? Global assessment of water shortage over the last two millennia", *Environmental Research Letters*, vol. 5, No. 3 (2010), 034006; M. Kummu and others, "The world's road to water scarcity: shortage and stress in the 20th century and pathways towards sustainability", *Scientific Reports*, vol. 6 (2016), 38495.

[147] OECD, OECD *Environmental Outlook to 2050: The Consequences of Inaction* (Paris, 2012).

[148] OECD (2012).

[149] Jack Keller, Andrew Keller and Grant Davids, "River basin development phases and implications of closure", *Journal of Applied Irrigation Science*, vol. 33, No. 2 (1998), p. 145–163; François Molle, "Development trajectories of river basins: a conceptual framework", Research Report, No. 72 (Colombo, Sri Lanka, International Water Management Institute, 2013).

- In the allocation phase, water availability is limited and decisions need to be made for the allocation or reallocation of water between different uses, without causing harm, and consistent with the principles of international law and the law of treaties.[150]

Each of the phases consists of different water management practices, such as water diversions and storages and, in the later phases, demand reduction. These practices aim to balance the water availability with (growing) water demand.

CASE STUDY 14: **Storage infrastructure and joint monitoring for flow reallocation needs in the lower Orange–Senqu River system**

The Orange–Senqu River system in Southern Africa, shared by Botswana, Lesotho, Namibia and South Africa, is highly regulated, because of the historical and ongoing extensive abstraction and dam infrastructure deployed in the upper and middle section of the river to address demand gaps. The lower Orange–Senqu region is well known for producing table grapes and other fruits for the export market in Europe and other parts of the world. Due to its unique climate and rich soils, the region enjoys early harvests and is therefore very competitive and is of significant national economic importance. The challenge to the irrigation farmers hinges on access to predictable and adequate water flow, especially during the season when the farming operations need such flow. Another challenge is ensuring adequate flows for ecological functions, including the river mouth, which is designated as a wetland of international importance (Ramsar site) on both sides of the common border.

The Noordoewer/Vioolsdrift Joint Irrigation Authority (JIA) was established in 1992 to enable Namibia and South Africa to jointly operate and maintain a canal built in the 1930s to supply water for irrigation, and control abstraction of water to farmers in the river valley on both sides of the border through a weir close to the border towns of Noordoewer and Vioolsdrift. In conjunction, the Permanent Water Commission (PWC) between Namibia and South Africa, also established in 1992, was mandated to advise the State parties on matters related to development and utilization of water resources of common interest to them. In relation to water allocation in the area of the JIA, the two State parties adopted volumetric allocation set at 20 million m^3 per annum in 1992. However, water needs for the region have been increasing, mainly as a result of increased productivity and increased uses upstream of the region. Complaints have been reported on the insufficient flows and inadequate water for irrigation, especially during the October to February period when the farmers need it most.

In order to address the allocation challenges, Namibia and South Africa identified a solution to build a flow- regulation dam at Noordoewer/Vioolsdrift. The purpose of the flow-regulation dam is to secure sustainable long- term water resources yield for the lower Orange–Senqu River, including environmental allocations for the river mouth. In this regard, the dam would serve the purpose of retaining any additional flow releases from upstream during the winter months, as well as scheduled flow releases and flood water during the rest of the year, and release the required flows according to farmer needs and to address ecological flow requirements towards the river mouth.

The Orange–Senqu River Commission (ORASECOM), the river basin authority established in 2000, is mandated to provide technical advice to the four State parties, in utilization, development, conservation and management of the overall basin. The ORASECOM IWRM plan articulated joint measures, including a suite of infrastructure solutions and environmental initiatives, to promote cooperation and sustainable

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[150] David Molden, R. Sakthivadivel and M. Samad, "Accounting for changes in water use and the need for institutional adaptation", in *Intersectoral Management of River Basins: Proceedings of an International Workshop on 'Integrated Water Management in Water-Stressed River Basins in Developing Countries: Strategies for Poverty Alleviation and Agricultural Growth', Loskop Dam, South Africa, 16–21 October 2000*, C. L. Abernethy, ed. (Colombo, Sri Lanka, International Water Management Institute and German Foundation for International Development (DSE), 2001), p. 73–87.

development of the shared river basin, in its entirety. The Noordoewer/Vioolsdrift dam feasibility study is currently ongoing, jointly financed by Namibia and South Africa. In the interim, the two States have installed gauging stations along the common border, equipped with advanced flow measurement and transmission capabilities. Joint field observations and monitoring of the flow gauging network continues, including joint field excursions to consult key role players such as local irrigation boards, water user associations and the JIA. The ORASECOM Secretariat has been co-opted to join the joint field excursions and consultations with key role players, especially when complaints regarding water allocations have been reported. The PWC regularly reports and updates ORASECOM on all major developments, including progress on deployment of the Noordoewer/Vioolsdrift dam.

b. Balancing water uses and needs in transboundary water allocation

Transboundary water allocation today and in the future needs to balance multiple growing needs and, at the same time, deal with the increasingly limited and varying availability of water. Furthermore, different water uses have different scopes for coping with change and improving efficiency. Allocation in a transboundary context may thus include difficult and potentially contested decisions on water use priorities. The allocation process requires the assessment of available water resources and understanding of different water uses and needs across both temporal (current and future uses) and spatial (in different States, jurisdictions and geographical, hydrographical and geohydrographical settings) scales. It should address water availability, water entitlements and the potential conflicts among different water use needs in terms of water quantity, quality and timing. In cases where all water use needs and demands cannot be met with the available water resources, parties need to discuss their priority at both transboundary and national levels.

CASE STUDY 15: **Determining allocation priority uses and proposal for a risk-based approach in the Incomati River Basin**

The Incomati River Basin is a transboundary watercourse in southern Africa. It covers approximately 46,500 km^2 shared by South Africa (28,600 km^2, 61 per cent), Mozambique (15,300 km^2, 33 per cent) and Eswatini (2600 km^2, 6 per cent). The Basin is in a relatively semi-arid area with annual rainfall in the order of 750 mm. Like elsewhere in Africa, inter- and intraannual variability in rainfall is high. Droughts prevail in some years, floods in others. The Kruger National Park, an internationally recognized hotspot for wildlife, covers a large portion of the Basin.

The current Interim IncoMaputo Agreement (IIMA), signed by the three countries in 1998, makes water allocations that distinguish between so-called First Priority Use and Irrigation Use and specify the amount of water for maximum utilization under "average" conditions. However, as assurances of supply are not specified, the IIMA does not explicitly address situations where a water deficit occurs. The IIMA does not include environmental flow requirements as a consumptive water use but allows for minimum in-stream flows at key points in the Incomati watercourse to sustain the ecology.

The IIMA allocated water based on past water use and estimates of the availability of water in 2002 to the three countries for first priority supplies, irrigation and afforestation in the Incomati Basin. The Tripartite Permanent Technical Committee (TPTC) comprising representatives of South Africa, Mozambique and Eswatini, has also agreed and implemented the Progressive Realization of the IncoMaputo Agreement (PRIMA) since 2010, upon which current allocations are based. Moreover, when the TPTC determines that a drought condition exists and that water use by the parties must be reduced, irrigation use shall be the first to be reduced.

The IIMA allocations may need to be revisited, as the most recent hydrology study of the Komati, Crocodile and Sabie subcatchments recorded less water than was originally assumed, due in part to the effects of climate change. A risk-based approach has been proposed for the allocation of water in the Incomati Basin, i.e. assurances of supply are assigned to the various user sectors in the system. This approach allows for greater flexibility while providing a consistent manner in which to operate the overall Basin. For each user category, allocations are refined into proportions for risk categories that should be supplied at different levels of assurance. This means, for instance, that an irrigator will have a large proportion of his or her water at a low assurance and a small proportion at a much higher assurance, while, conversely, a first priority user may have a large proportion or all of his or her water at a high assurance and a small proportion at a lower assurance. Included in the allocation system are mechanisms to realize the potential benefits that could accrue during a surplus situation. The risk-based approach, however, provides the flexibility for water users to adapt to both situations, whether surplus or deficit.

Decisions on balancing water uses are generally informed by socioeconomic aspects, existing water uses, assessments of environmental requirements and pre-existing institutional frameworks, among other factors. Such decisions are best coordinated as part of basin-wide planning, integrating consideration of future scenarios, BAT and water management practices. Principles of international water law, including equitable and reasonable utilization, no significant harm, and protection of the environment, as well as the human right to water, provide a guiding framework for negotiations (see Chapter V, subsection 3c). Considering that water allocation for human consumption, some national security-related uses and environmental requirements have limited scope for negotiation, the socioeconomic aspects should be analysed in detail, providing opportunities to understand how to make interventions in different water uses, and what both the best practices and the potentially sensitive and contested aspects are.

Socioeconomic aspects commonly focus on water-related livelihoods and economic sectors such as agriculture, industry and energy production, cultural features and well-being, including domestic water supply, as well as broader food security and energy security issues. The water needs for the different socioeconomic uses need to be evaluated against, and aligned with, the overall development and climate scenarios in the given context (see Chapter II section 1; Chapter VI section 4). Furthermore, after water for vital human needs and the environment has been allocated, national allocation among sectors may be made based on highest value uses (economic, cultural) (see also subsection 3c above).[151] In a transboundary context, benefit-sharing and a nexus approach may provide means to further balance the socioeconomic interest of different parties and address challenging upstream–downstream dynamics (see also Chapter IV).[152]

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[151] OECD, *Water Resources Allocation: Sharing Risks and Opportunities* (2015).

[152] UNECE, *Policy Guidance Note on the Benefits of Transboundary Water Cooperation* (2015); UNECE, *Methodology for Assessing the Water-Food-Energy-Ecosystems Nexus* (2018).