WATER RESOURCES PROFILE SERIES

The Water Resources Profile Series synthesizes information on water resources, water quality, the water-related dimensions of climate change, and water governance and provides an overview of the most critical water resources challenges and stress factors within USAID Water for the World Act High Priority Countries. The profile includes: a summary of available surface and groundwater resources; analysis of surface and groundwater availability and quality challenges related to water and land use practices; discussion of climate change risks; and synthesis of governance issues affecting water resources management institutions and service providers.

Mozambique Water Resources Profile Overview

- Mozambique has abundant surface and groundwater, although 54 percent of its freshwater resources originate in upstream countries. Water stress at the national scale is low as total renewable water resources per capita (7,317 m^3) is higher than the water stress threshold defined by the Falkenmark Water Stress Index[i] and the total volume of freshwater withdrawn by major economic sectors is only 1.75 percent[ii]. However, water is not evenly available throughout Mozambique and many water courses are seasonal, which can contribute to regional water stress, especially in the south and during times of drought.
- Upstream over-abstraction and pollution and climate change impacts from more intense coastal cyclones, increased flooding, and higher frequency of drought are key risks to water resources.
- High inter-annual and inter-seasonal rainfall variability in the south, in addition to increasing irrigation and abstractions from upper riparian states, constrain surface water availability.
- Transboundary frameworks and legal instruments generally do not guarantee minimum flow or water quality on the Umbeluzi, Limpopo, Save, Buzi, and Zambezi Rivers.
- While hydropower generation on the Zambezi River is a key priority, biodiversity and ecosystems are at risk from reduced wet season flow and sedimentation.
- Surface and groundwater quality are not well understood. Saline groundwater can be found in coastal aquifers and there is evidence that mining is polluting surface waters with toxic heavy metals in the Limpopo and Zambezi Basins.
- Climate change will increase the frequency of drought and flood risks. Catastrophic flooding in the south has been responsible for infrastructure damage and loss of human life.
- Basin-level water resources management entities often lack technical and organizational capacity and struggle to collect water use permit fees, which impedes implementation of operational plans, stakeholder engagement, and water quality monitoring mandates.

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[i]The Falkenmark Water Stress Index measures water scarcity as the amount of renewable freshwater that is available for each person each year. A country is said to be experiencing water stress when water availability is below 1,700 m^3 per person per year; below 1,000 m^3 is considered water scarcity; and below 500 m^3 is absolute or severe water scarcity.

[ii]SDG 6.4.2 measures water stress as the percentage of freshwater withdrawals against total renewable freshwater resources. The water stress thresholds are: no stress <25%, low 25%-50%, medium 50%-75%, high 75%-100%, and critical >100%.

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Water Resources Availability

KEY TAKEAWAYS

- Mozambique receives surface water from several large transboundary rivers, including the Zambezi River which provides most of Mozambique's water resources.
- Groundwater is readily available at shallow to moderate depths throughout Mozambique, and the most hydrologically productive aquifer system is the Mozambique Sedimentary Basin south of the Save River.

This section summarizes key characteristics of surface and groundwater resources. Table 1 summarizes key water resources data and Figure 1 presents key surface water resources, wetlands, and dams.

Surface Water Resources

Mozambique has 13 major river basins (nine are transboundary) and 22 smaller basins scattered along the coastline.[3] The northern region contains the majority of the smaller coastal basins, in addition to major basins such as the Lurio, Licungo, and Rovuma Basins. The Pungoe, Buzi, Save, and Zambezi Basins in central Mozambique are major transboundary basins. The Zambezi is the largest, spanning eight countries and with headwaters in Angola. Southern Mozambique features the Limpopo Basin, which spans four countries, as well as the Save, Incomati, Umbeluzi, and Maputo Rivers. The Zambezi River constitutes around 58 percent of renewable surface water, followed by the Rovuma River (13 percent).[1,3] Most rivers have high water flow between December and March and low flow for the rest of the year. Mozambique also has more than 1,300 small lakes and six main artificial reservoirs. The two main lakes are Lake Niassa (Lake Malawi), which is shared with Malawi and Tanzania, and Lake Chirua (Lake Chilwa), which is also shared with Malawi.[3,4]

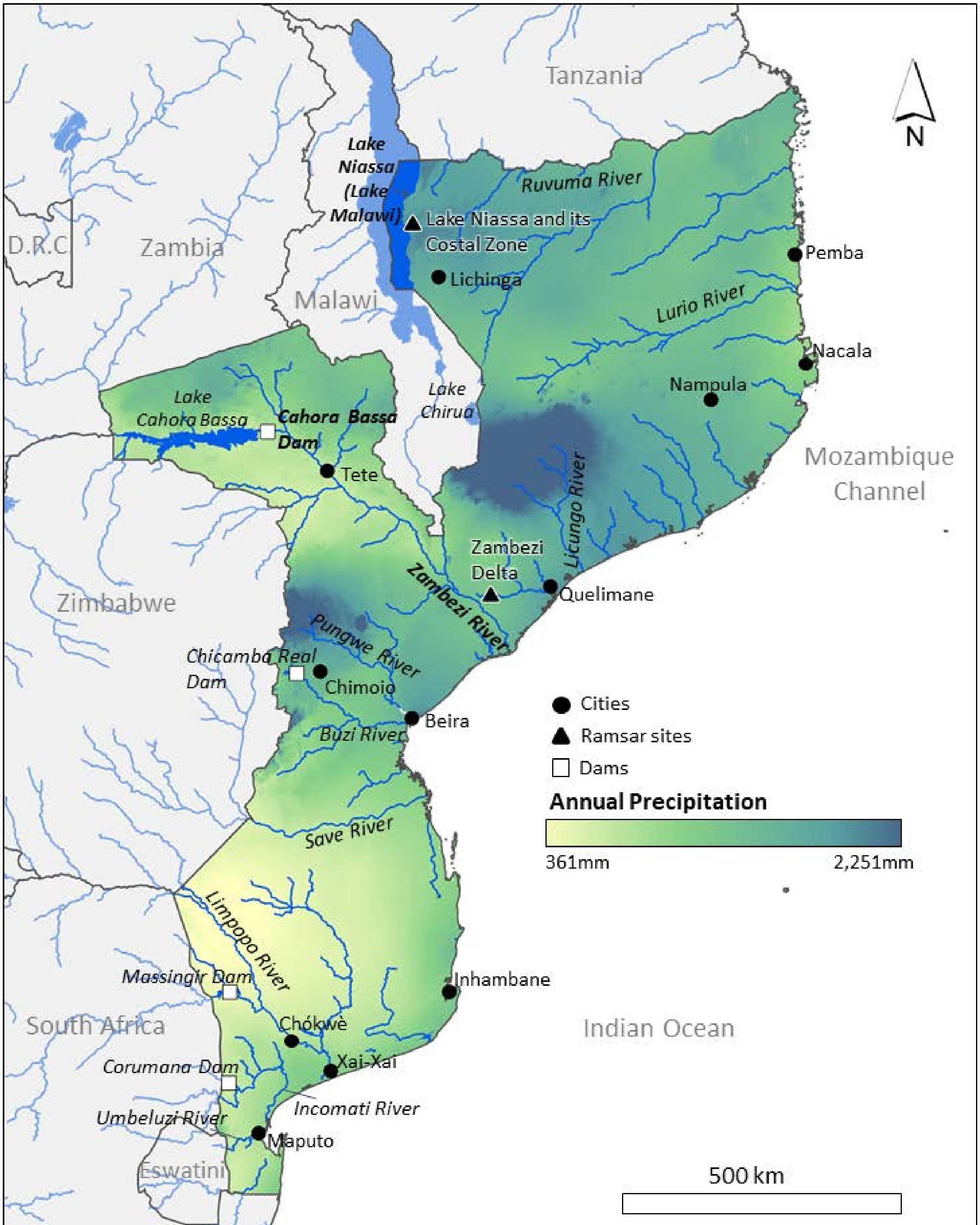
Groundwater Resources.

West central and northern Mozambique is generally underlain by basement complexes with low productivity, although conditions can vary.[5,6] Volcanic aquifers are present to a limited extent along the southwestern border and in the central region, although these aquifers generally have low productivity.[6] Sedimentary aquifers are much more hydrologically productive and underly most of the rest of Mozambique, primarily in the southern and east central regions. The unconsolidated Mozambique Sedimentary Basin south of the Save River is most productive whereas the central Mozambique Sedimentary Basin north of the Save River is less productive.[5,6] Well yields in the southern sedimentary basin range from 1.4 liters per second (L/s) to 5.6 L/s in the Limpopo and Incomati Basins.[5] Yields in basement complexes rarely exceed 1.94 L/s while volcanic aquifers average around 0.8 L/s.[5] Groundwater can usually be accessed at shallow to moderate depths, although boreholes as deep as 100m can be found in the north.[5] In general, aquifer yields are more productive closer to the

TABLE 1. WATER RESOURCES DATA	Year	Mozambique	Sub-Saharan Africa (median)
Long-term average precipitation (mm/year)	2017	1,032	1,032
Total renewable freshwater resources (TRWR) (MCM/year)	2017	217,100	38,385
Falkenmark Index - TRWR per capita (m3/year)	2017	7,317	2,519
Total renewable surface water (MCM/year)	2017	214,100	36,970
Total renewable groundwater (MCM/year)	2017	17,000	7,470
Total freshwater withdrawal (TFWW) (MCM/year)	2002	1,473	649
Total dam capacity (MCM)	2015	74,140	1,777
Dependency ratio (%)	2017	53.8	23
Interannual variability	2013	3.5	1.55
Seasonal variability	2013	3.3	3.15
Environmental Flow Requirements (MCM/year)	2017	133,000	18,570
SDG 6.4.2 Water Stress (%)	2002	1.75	5.7

Source: FAO Aquastat

FIGURE 1: MAP OF WATER RESOURCES



Source:
Cities: World Cities – ArcGIS Hub, **Country Borders:** GADM, **Dams:** FAO Aquastat Dams Database, **Ramsar Sites:** Ramsar Sites Information Service, **Lakes and Wetlands:** WWF - GLWD (Level 1), **Rivers:** WWF – HydroRivers, **Precipitation:** WorldClim, **Flood and Drought:** WRI Aqueduct 2019

coastline.[6] Aquifer recharge rates can range from 5 to 30 percent of total annual precipitation, and average around 10 percent nationally.[3] The highest recharge rates are in the sedimentary aquifers along the central coast and in the south.

Surface Water Outlook

KEY TAKEAWAYS

- Southern Mozambique is the most water scarce and drought-prone region and is also vulnerable to flooding. A significant portion of current and proposed irrigation schemes are concentrated in the south.
- Dams on the Zambezi River reduce wet season flows and sediment transport to the Zambezi Delta.
- Surface water quality concerns are linked to upstream pollution, domestic gold and coal mining, inadequate sanitation systems, and agriculture.

This section describes key sources of demand and uses of surface water, and associated challenges stemming from water availability and water quality challenges.

Southern Mozambique experiences seasonal water stress and is highly susceptible to drought and floods. Surface water inter-annual and inter-seasonal variability is high in southern Mozambique.[7] For example, the Limpopo River can run dry for three to four months in a normal year, and sometimes up to eight months.[8] Additionally, the Limpopo Basin experiences severe drought every seven to eleven years.[7] Intensive upstream irrigation and development of water resources have reduced river flows on the Incomati and Maputo Rivers by 50 and 30 percent respectively.[3] Cyclones also elevate flood risk, especially in southern Mozambique. In 2000, cyclone Leone-Eline led to major flooding that caused around USD $550 million in damages and affected more than 2 million people in the Limpopo, Maputo, Umbeluzi, Buzi, and Save Basins.[3,8] Mozambique's 2018 National Master Plan for Water Resources Management calls for the construction of almost 470 km of levees along riverbanks to protect against flooding.[3]

Upstream and domestic dams create risks to ecosystems, including biodiversity loss, especially in the Zambezi Delta. Water storage capacity is relatively high but concentrated in the Zambezi's Cahora Bassa Dam, which is Africa's second largest dam. It generates 75 percent of Mozambique's power and constitutes 70 percent of national reservoir storage capacity.[9–12] The proposed Lupata, Boroma, and Mphanda Nkuwa, and Cahora Bassa North projects in the Zambezi Basin would double national power capacity through several new dams.[3,10]

While dams can stabilize water resources availability, mitigate damaging floods, and provide key benefits such as hydropower, they also disrupt natural flow patterns which can negatively impact downstream ecosystems. The Zambezi Delta spans 3,000 km2 and is a global biodiversity hotspot.[13] Since its construction, the Cahora Bassa Dam has reduced wet season flows by 61 percent and increased dry season flows by 243 percent.[14] Reduced wet season flows and flow disruptions from the Cahora Bassa Dam have reduced sediment transport to the Zambezi Delta and increased brackishness as seawater penetrates farther inland.[15]

Water quality is impacted by mining in upper basin countries, urban wastewater, and agricultural effluent. Water quality samples in the Limpopo Basin near Mozambique's international borders indicated high levels of heavy metals and fecal coliforms.[16] Specifically, cadmium and lead were found to exceed WHO guideline values for drinking water by a magnitude of 14 to 45 times, respectively.[16,17] Algal blooms, typically linked to municipal waste or agricultural runoff, have also been observed in Nhambavale Lake, which is used for recreation and as a source for drinking water in Gaza Province.

Coal mining in the Zambezi Basin and gold mining contaminate surface water with acidic drainage and toxic heavy metals. In the Zambezi Basin, coal mining near the Cahora Bassa Dam has contaminated key tributaries, which contribute 29 percent of the domestic flow into the Zambezi, with heavy metals.[18] Artisanal and large-scale gold mining in the Manica Province has reduced pH, increased turbidity, and contaminated surface water with arsenic and chromium.[19]

Groundwater Outlook

KEY TAKEAWAYS

- Most groundwater abstractions are for domestic use, although the sustainability of these abstractions is not well understood.
- Groundwater quality data is lacking, although saline encroachments from natural and anthropogenic sources have been documented along the coast and in southern Mozambique. Studies on pathogenic contaminants indicate that poor well construction and heavy rainfall contribute to seasonal groundwater quality risks.

This section describes key sources of demand and uses of groundwater, and associated challenges stemming from water availability and water quality challenges.

Most groundwater abstractions are for domestic use, although the sustainability of these abstractions is not well understood. Around two-thirds of the population uses groundwater for domestic purposes, mostly through unprotected wells,[3] and some estimates suggest that 30 percent of all abstractions are from non-renewable sources.[20] Boreholes and wells are more concentrated in and around population centers, especially in the south, and serve as a primary source of municipal supply in cities such as Pemba, Tete, Xai-Xai, Quelimane, and Chokwe.[3] Groundwater use is also common in rural areas[21] and is used to a lesser extent for irrigation by smallholder farmers and for livestock watering.[3] Large-scale abstractions for agriculture are low as the most productive aquifers tend to be located in areas that are not suitable for agriculture or where surface water is abundant.[8]

Comprehensive testing is needed to confirm the risks posed by geogenic contaminants. Groundwater quality information in Mozambique is generally limited and additional research is needed to understand the risks of geogenic contaminants like fluoride in the north near the Great Rift Valley, where documented fluoride contamination is widespread.[22] Arsenic is often present near alluvial gold deposits and may threaten groundwater in river valleys and the Zambezi Delta.[22]

High salinity in groundwater is caused by natural and anthropogenic sources, particularly in the south. An estimated 10.5 percent of the country is affected by brackish groundwater, much of which is naturally occurring, although over-pumping in coastal aquifers also exacerbate salinity.[3] Groundwater quality tests in the south indicated that electrical conductivity, which correlates with salinity, is in excess of World Health Organization (WHO) guideline values for drinking water and precludes use for agriculture and livestock watering.[5] Salinity in the Great Maputo Aquifer has been attributed to a naturally saline confining layer in the aquifer[23] and salinity was confirmed to be high in inland aquifers, including in the Limpopo National Park in southern Mozambique.[24]

Fecal contamination of groundwater in urban areas may be widespread during the rainy season but more research is needed. A water quality study around the peri-urban areas of Maputo indicated that fecal contamination was not widespread due to the low infiltration rates and because the thick unsaturated layer (10 to 30 meters) safeguarded groundwater quality. Other studies have concluded that groundwater contamination can depend on precipitation. A survey of wells in northern Mozambique found that nitrate concentrations and fecal contamination were low for most of the year, but fecal coliforms spiked at the start of the rainy season.[25]

Water Resources and Climate

KEY TAKEAWAYS

- Mozambique is highly vulnerable to drought. Climate change may decrease precipitation slightly, increase the likelihood of drought, and increase evaporation rates.
- Mozambique faces recurrent threats from cyclones, which may decrease in frequency but increase in intensity. Cyclones exacerbate flood risks, especially during peak river flows during the wet season.

This section covers climate variability and climate change, their impacts on water availability and water quality, and the risks they pose to local communities and their economies.

Climate change is expected to increase temperatures and alter precipitation patterns. Average annual precipitation is 1,032 mm, with rainfall ranging from over 2,000 mm per year in the north and some parts of central Mozambique to around 500 mm in the southwest.[4,26] Rainfall mainly occurs during the hot season, from October to March, with drier conditions during the cool season throughout the rest of the year.[27] Global climate models project that temperatures will increase between 2.0 and 3.9°C.[28] Climate change's impact on precipitation is less certain but total annual precipitation may decrease between 50–90 mm/year, primarily between October and December, with additional water losses from increased evaporation.[28]

Climate change may lead to more severe drought and flooding. Evaporation rates and drought are projected to increase by later this century.[28] Droughts have collectively damaged over 8 million hectares of crops and impacted over 11 million people between 1990 and 2009.[29] Droughts are more likely to affect Mozambique during El Niño years, especially in the more arid south. The 1982-1984 drought was one of the most severe droughts in modern history, impacting one-third of the population and causing a famine that claimed over 100,000 lives.[3,30] The 2015-2016 drought was caused by a particularly strong El Niño event and led to food insecurity for 1.5 million people and caused crop failure across one-fifth of croplands, primarily in southern, central, and northwestern Mozambique.[26,31]

Flooding is common along the Zambezi River[2] and in the Limpopo Basin. More intense rainfall is expected to increase flood peaks 25 percent.[32] However, national trends regarding heavy precipitation events are less clear.[28]

Climate change is expected to reduce the frequency and increase the intensity of cyclones. Annual cyclones will continue to threaten infrastructure, livelihoods, and human lives, as roughly half that enter the Mozambique Channel make landfall.[2,35] The impacts of cyclones are projected to worsen through a combination of sea level rise and urbanization along the coast.[2,26] Cyclones may be particularly devastating when they coincide with high tide or peak wet season flows, as occurred in 2019 with cyclone Idai, one of the strongest on record in the West Indian Ocean.[2] Idai impacted 1.85 million people, resulting in 600 deaths; totally or partially destroyed over 200,000 houses; and caused a deadly cholera outbreak.[36]

FIGURE 2: DROUGHT RISK

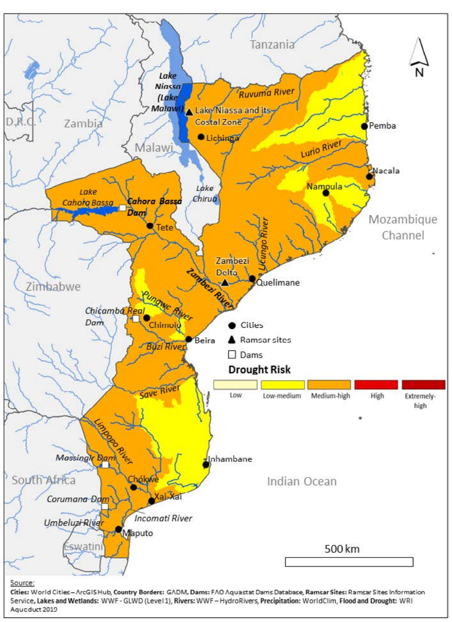
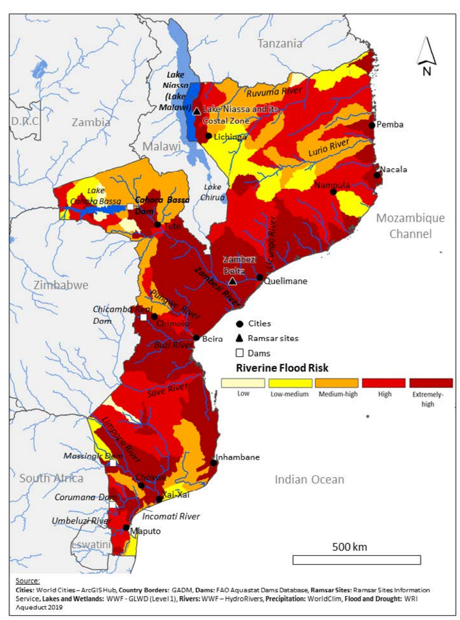


FIGURE 3. RIVERINE FLOOD RISK



Water Policy and Governance

KEY TAKEAWAYS

- Regional Water Administrations (ARAs) are underfunded and struggle to collect needed resources to fulfill their core functions. Technical and organizational capacity within the ARAs is low and operational plans often underemphasize groundwater development and do not apply cross-sectoral and comprehensive approaches to conservation and pollution control.
- Organizational and legal frameworks for transboundary river basins frequently lack specific instruments to safeguard water flow and quality.
- More comprehensive water quality monitoring is needed nationwide to protect water resources. ARA water quality monitoring is conducted on some key rivers, while groundwater quality monitoring is limited.

This section provides an overview of key policies, institutions, and management challenges. Key laws, policies, and plans are summarized in Table 2 and the roles and responsibilities of select transboundary, national, and sub-national water management entities are summarized in Table 3.

Technical and institutional capacity constraints impede IWRM. The performance of the five ARAs is variable and depends on technical capacity and resources. The ARA-Zambezi and ARA-South, which oversee the Limpopo, Incomati, Maputo, and Umbeluzi Basins, are among the best performing and have the highest capacity, whereas the ARA-North is the weakest and most under-funded.[37] Stakeholder engagement within the ARAs occurs through RBCs, however, these committees may only meet once or twice a year.[38] The opinions of downstream stakeholders are not always comprehensively considered in relation to major hydraulic infrastructure proposals.[38]

Insufficient funding and a lack of sustainable financing creates a high dependency on external support. An estimated 85 percent of funding for the water sector is derived from grants and concessional loans.[39] Funding for provincial services is also dependent on timely distributions from Ministry of Finance or the National Directorate of Water, however, technical capacity constraints impede financial management systems. The National Water Law outlines user- and polluter-pays principles to fund sector investments and governance. ARAs are in charge of licensing water users whereas licensing for discharge of effluent is managed by MICOA. However, lack of adequate staffing can significantly slow the licensing process for water users, which can delay revenues.[38] The central government, and not ARAs, is authorized to define water use fees. Legislation has focused on increasing water use fees.[40]

Despite having transboundary IWRM entities in all nine international basins, Mozambique is not always able to guarantee water supply and quality. Mozambique is a signatory to 14 agreements and memorandums of understanding (MoU) that define principles and commissions for joint management and water sharing with its riparian neighbors. The Southern Africa Development Community (SADC) Protocols set guidelines for water sharing negotiations, however, existing MOUs and agreements often do not define water allocations or minimum quality standards.[8] Only the Maputo, Incomati, and Pungoe Rivers have treaties which quantify minimum river flow requirements.[3] One of ZIMCOM's mandates is to conserve water supply

TABLE 2. OVERVIEW OF KEY LAWS, POLICIES, AND PLANS

Name	Year	Purpose
National Water Law	1991	Adopts IWRM-based approach to water management and assigns institutional responsibilities across the water sector, with the Ministry of Public Works, Housing and Water Resources (MOPHRH) serving as the primary national authority on water resources management and policy development. Establishes the National Water Council (CNA) and Regional Water Administrations (ARAs)
National Water Policy	1995	Assigns water resources management functions to basin and provincial level organizational structures. Revised in 2007 emphasized IWRM priorities.
National Master Plan for Water Resources Management ("Master Plan")	2018	National plan for water resources management for the next 20 years, which includes water balance and flood risk analyses, and prioritizes hydraulic investment planning.

TABLE 3: OVERVIEW OF KEY IWRM ENTITIES

Mandate	Institution	Roles and Responsibilities
Transboundary	Limpopo Watercourse Commission (LIMCOM)	Established in 2014, LIMCOM is a platform for transboundary governance of the Limpopo River Basin shared between Botswana, Mozambique, South Africa, and Zimbabwe. Encompasses both surface and groundwater management within the basin.
	Zambezi Watercourse Commission (ZAMCOM)	Established in 2011, ZAMCOM is an organizational framework for governance of the Zambezi River Basin, which is shared among eight countries (Zambia, Angola, Namibia, Zimbabwe, Botswana, Malawi, Tanzania, and Mozambique).
	Joint Water Commissions (JWCs)	Three independent JWCs exist: 1) JWC for Zambia and Mozambique for the Pungwe, Buzi, and Save Basins; 2) JWC for Swaziland and Mozambique for the Umbeluzi Basin; and 3) JWC between Tanzania and Mozambique for the Rovuma River.
	Inkomati Tripartite Permanent Technical Committee (TPTC)	Promotes collaboration between South Africa, Swaziland, and Mozambique on Inkomati and Maputo Rivers, especially to mitigate the effects of flood and drought.
National	Ministry of Public Works, Housing and Water Resources (MOPHRH)	Created in 2015, the MOPHRH is the lead ministry in charge of the water and sanitation sectors, focusing on infrastructure, policy, and regulation.
	National Directorate of Water Resources Management (DNGRH)	Housed within the MOPHRH. Responsible for developing water management policies for river basins; ensuring compliance with international treaties on shared water resources; performing regular analysis and assessment of water availability and demand from river basins; and formulating and managing basin-wide water management plans.
	Ministry for the Coordination of Environmental Affairs (MICOA)	Issues permits and collects fees for effluent discharge.
	National Water Council (CNA)	Inter-ministerial entity tasked with water sector coordination. Advises the Council of Ministers on issues related to water management and policy, including the implementation of the 1991 Water Law.
	Ministry of Land, Environment, and Rural Development (MITADER)	In charge of permitting for environmental impact assessments.
Sub-national	Regional Water Administrations (ARA)	Five autonomous ARAs are supported and coordinated by the DNGRH. Manage Beneficiary Management Units (UGBs). Responsible for planning and developing basins; dam operations and management; overseeing licensing and concessions for water management; collecting and analyzing hydrological data; establishing protected areas for both surface and groundwater conservation; and managing conflicts among water users for major basins.
	Basin Management Units (UGB)	13 UGBs are managed by ARAs and oversee management of water resources, hydrologic data collection and storage, flood monitoring, water user data collection, collection of water tariffs, implementation of basin level plans and strategies, and promotion of stakeholder participation.
	River Basin Committees (RBC)	11 consultative and advisory platforms for ARAs to promote water use efficiency and environmental protection. Composed of water user representatives, with meeting agendas and frequencies dictated by ARAs/UGBs.

and quality, but international priorities favor economic development. Malawi has a vested interest in mining and fossil fuel extraction in and around Lake Malawi and throughout Zambia. As of 2012, there were plans for at least 14 new upstream dams for irrigation and hydropower on the Zambezi and its tributaries.[41] Given these upper basin economic interests, the lack of strict water quality standards and protections, and the absence of clear water allocations among member states for many rivers, Mozambique does not have legal guarantees to assure water supply.

Water Quality Monitoring

Surface water and groundwater quality is not consistently or comprehensively monitored. There are 34 surface water quality stations under the jurisdiction of ARAs, although no monitoring has been conducted by the ARA-Centro-Norte and ARA-Norte.[3] Where monitoring networks are functional, data collection processes are slow and funding to increase monitoring coverage and increase reliability has not been sufficient. Groundwater quality is not routinely monitored and the ARA-Sul Pilot Project is the only national groundwater monitoring program, which collects data from 48 water points within the Maputo metropolitan area.[3,42] There is limited water quality monitoring coordination between transboundary riparian countries.[16]

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