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.

Mali Water Resources Profile Overview

Total renewable freshwater resources are well above the average in sub-Saharan Africa and most renewable water supplies are from surface water. Half of all water resources originate outside Mali, including the Niger and Senegal Rivers, which can impact domestic water security and freshwater availability varies significantly by region and across seasons, contributing to significant water shortages in some parts of the country, particularly in the northern Saharan and Sahelian zones. According to the Falkenmark Index[i] and SDG 6.4.2[ii], Mali is not experiencing national level water stress, as total renewable water resources per person (6,472 m^3) is above the water availability stress threshold and abstraction rates (8 percent) are below the 25 percent water stress threshold set by the Food and Agriculture Organization. The duration and severity of droughts are expected to increase while hotter temperatures will raise evaporation rates and reduce overall surface water supply.

The highly variable inter-seasonal and inter-annual flow of the Niger River, combined with more frequent and severe droughts, have reduced dry season water availability in central and eastern Mali. Specifically, upstream irrigation and hydroelectric power generation are reducing downstream flows required to sustain river stages and flood levels critical to fluvial transportation, agriculture, fisheries, and viable dry season animal husbandry.

The planned transboundary Fomi Dam on the upper Niger River in Guinea will stabilize the regional electrical grid, increase irrigation for nearby agriculture, increase and stabilize dry season flow rates, and enable more predictable land use planning in the Inner Niger Delta (IND). However, dam outflows during the wet and dry seasons must consider the impacts on vulnerable ecosystems in the IND and local livelihoods.

Inadequate sanitation systems, municipal solid waste, and effluents from mining, tanneries, and dyeing industries degrade water quality and ecosystems in the IND. Chemical contaminants in surface water can bioaccumulate (especially lead) and affect public health, as fish-based diets represent a key pathway for toxin ingestion.

Groundwater is the primary source for drinking water and domestic use nationally, however, insufficient groundwater quality monitoring and protection schemes increase public health risks, particularly in cities like Bamako. Pathogenic contamination in shallow aquifers is caused by poorly constructed and unprotected wells and infiltration of latrine waste. Data on chemical contamination is constrained due to limited groundwater quality testing.

Staff capacity and funding constraints impede water resources management planning and implementation of basin and sub-basin water management plans and increase reliance on donor assistance.

[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%.

Water Resources Availability

KEY TAKEAWAYS

- Wet and dry season river flow regimes form West Africa's largest wetland at the Inner Niger Delta (IND) in central Mali, which peaks in October and recedes by the following summer.
- The Niger River is the longest and most important river in Mali and traverses most of the country from west to east, followed by the Senegal River in Western Mali.
- Northern Mali is arid and has no perennial surface water and limited precipitation, but nonrenewable groundwater reserves are abundant (fossil water).
- Groundwater is widely available, although groundwater levels and recharge are highest in the IND.

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

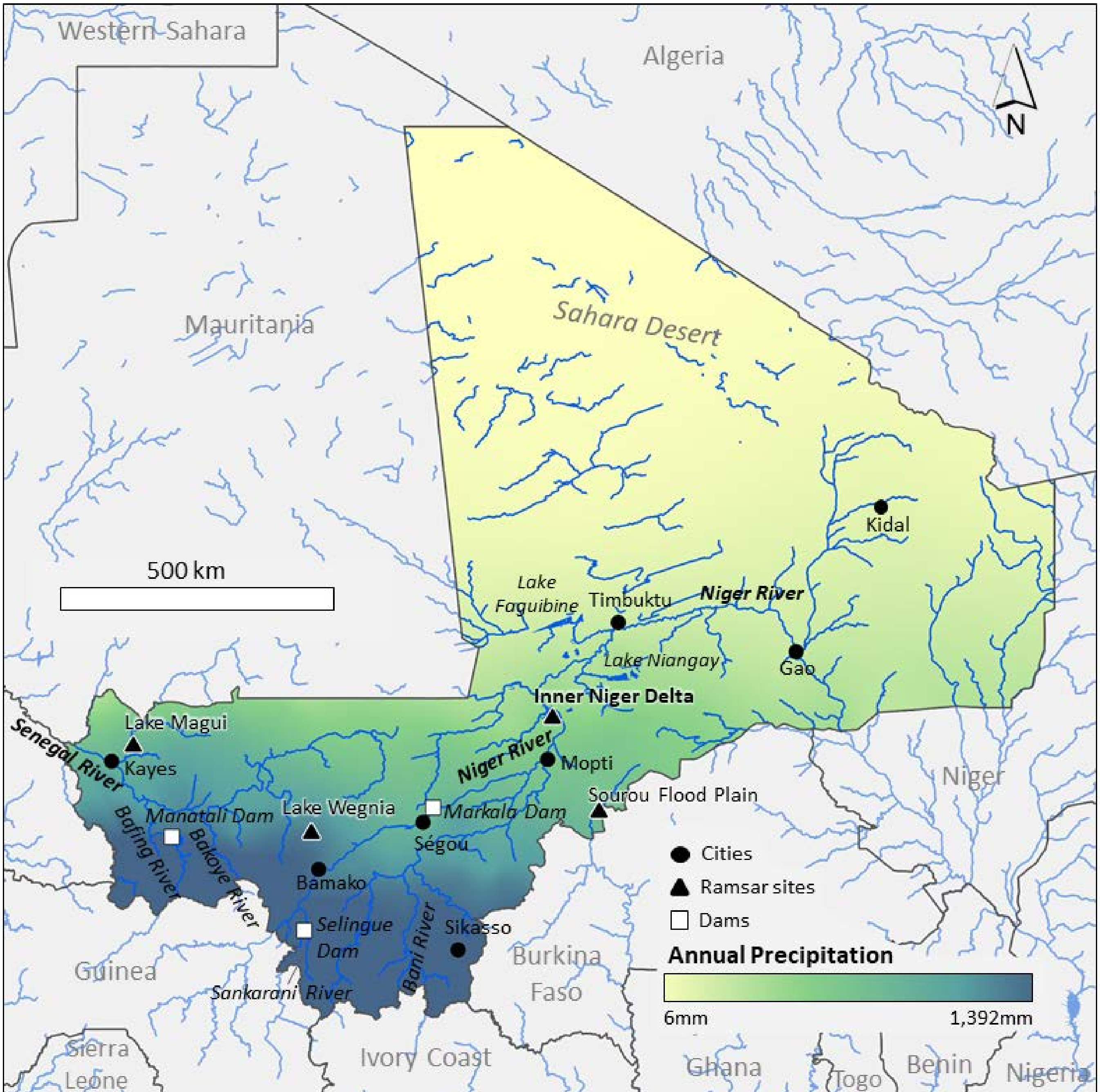
Mali has three main river basins: the Niger (47 percent), Senegal (11 percent) and Volta (1 percent). Approximately 41 percent of the country is in the Sahara Desert.[4] The Sahara Desert lacks perennial surface waters but seasonal wadis are important for wildlife and nomadic pastoralists. The Bafing and Bakoye Rivers, which originate in Guinea, are the headwaters to the Senegal River and deliver an estimated eight million cubic meters (MCM) combined annually into southwestern Mali.[6]

The Niger River, which is Africa's third longest river and the largest river basin in West Africa, is Mali's most prominent waterbody.[5] The Niger River originates in the Guinean Highlands and delivers an average of 40 MCM into Mali annually.[6] The Niger River is augmented by the Bani and Sankarani Rivers and courses past most urban centers in the south, east, and central Mali before it crosses into Niger. The Niger feeds the four million hectare (ha) Inner Niger Delta (IND), which is critical wetland and the world's third largest Ramsar site.[9,10] Basin inflows to the IND average 1490 m^3/s but outflows are reduced by 40 percent to 900 m^3/s due to evaporation and groundwater infiltration.[7] The IND's lakes provide natural water storage capacity in addition to habitat for important biodiversity, however, their permanence, coverage, and depth can depend on the intensity and duration of the Niger River's wet season flows and the degree of sedimentation in the lakes and in their inflowing canals.[8] One of the largest lakes in West Africa, Lake Faguibine, stores 4 MCM of water and spans 590 km^2.[8]

TABLE 1. WATER RESOURCES DATA	Year	Mali	Sub-Saharan Africa (median)
Long-term average precipitation (mm/year)	2017	282	1,032
Total renewable freshwater resources (TRWR) (MCM/year)	2017	120,000	38,385
Falkenmark Index - TRWR per capita (m3/year)	2017	6,472	2,519
Total renewable surface water (MCM/year)	2017	110,000	36,970
Total renewable groundwater (MCM/year)	2017	20,000	7,470
Total freshwater withdrawal (TFWW) (MCM/year)	2002	5,186	649
Total dam capacity (MCM)	2015	13,790	1,777
Dependency ratio (%)	2017	50	22.78
Interannual variability	2013	1.30	1.55
Seasonal variability	2013	4.00	3.15
Environmental Flow Requirements (MCM/year)	2017	55,200	18,570
SDG 6.4.2 Water Stress (%)	2002	8.00	5.70

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

Four man-made hydropower dams with a total storage capacity of 13,790 MCM regulate surface water flows for flood control and store water for irrigation.[11] The Manantali (11,270 MCM capacity) is located on the Senegal River in western Mali, the Sélingué (2,170 MCM capacity) on the Niger River close to the Guinean border, and the Markala (175 MCM capacity) on the Niger River.[11]

Groundwater Resources

Despite low precipitation, groundwater resources are abundant and widespread across 80 percent of Mali.[12] Mali's aquifers are grouped within nine geologic formations. One of the most productive aquifer systems is the Continental Terminal formation, which underlays 16 percent of Mali in the central region along the path of the Niger River.[2] In this formation, boreholes are generally 20-60 meters (m) deep with robust aquifer thicknesses that can be upwards of 80m deep.[2,13]

Some of Mali's most productive aquifers can be found in the Sahelian and Saharan zones, however, this water is typically nonrenewable fossil water. Abstraction rates are low relative to supply as the land is not arable and population density is low. Annual groundwater recharge is robust (66,000 MCM/year) in the IND.[14] Borehole depths nationally average between 50m to 75m, with shallower depths along the IND and deeper wells in eastern Mali (100m-200m).[12]

Surface Water Outlook

KEY TAKEAWAYS

- Irrigation constitutes 99 percent of all water withdrawals. Flood irrigation for paddy rice fields is the most common irrigation technique around the IND and along the course of the Niger River.
- Extensive seasonal flooding in the IND is essential for food security, livelihoods, transportation, ecosystems, and biodiversity. Dams, projected increases in irrigation withdrawals, and droughts are reducing the extent of wet season flooding, which increases competition for water and contributes to regional conflict.
- Surface water quality is threatened by poor sanitation systems in urban areas as well as chemical contamination from gold mines, slaughterhouses, dyeing industries, and tanneries.
- The IND is the third largest Ramsar site in the world and its biodiversity and ecosystems may be at risk from the proposed transboundary Fomi Dam in Guinea.

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

Annual surface water withdrawals constitute 99 percent of total water withdrawals.[3] Seventy-nine percent of the population depends on agriculture and the vast majority are small shareholders who practice rain-fed cultivation.[15] Flood irrigation of paddy rice in southern portions of the Niger River and throughout the IND is the most prominent source of demand. The Office du Niger, which is one of the largest irrigation service providers, plans to irrigate an additional 330,000 ha near Segou by 2045, supplementing the 120,000 ha currently irrigated with water from the Markala Dam.[16] This would increase surface water withdrawals from the upper Niger River's annual flow from 7 to 27 percent.[17] Other consumptive uses include municipal supply, domestic use, and industry but these are small compared to irrigation.

The IND is home to over 1.5 million people and accounts for 80 percent of national fish harvests, 15 percent of cereal cultivation, and sustains 50 percent of Mali's livestock in the dry season.[18] Approximately 80 percent of the population living around the IND rely on waterways for transportation and shipping. The proposed Fomi Dam would regulate wet season flows and increase the predictability of downstream water availability. However, relatively small changes in river flow rates will have large effects on IND inundation coverage and target wet season inundations should account for minimum environmental flows and the needs of downstream stakeholders.

Prolonged droughts caused by climate change are reducing wet season inundation and inflows to important lakes. Under prolonged drought conditions, the scale of wet season inundation can shrink from 25,000 km^2 to 5,500 km^2 in the IND.[20] Prolonged drought conditions also contribute to sediment deposition in the inflowing channels, which can slow flow rates and inflows to the lakes.[22,23] Desertification and deforestation around the lakes as well as flooding have also increased direct sedimentation in lakes and reduced their volume.[9] Many once-permanent and extensive IND lakes have shrunk or become ephemeral. For example, Lake Faguibine, once Mali's largest permanent lake, shrank significantly in the 1990s after two decades of drought. In recent dry seasons, Faguibine has remained quite small or completely disappeared by the end of the dry season.

Climate change mitigation measures are underway to rehabilitate portions of the Niger River. The Government of Mali, the African Development Bank, and the World Bank have made recent investments to rehabilitate over 100 km of waterways through dredging and erosion control projects to keep waterways in the Segou and Mopti regions navigable. Erosion control measures such as reforestation of riverbanks will reduce sediment load and provide a scalable and long-term investment that will reduce the frequency and scale of routine dredging operations.

As riparian conditions and surface water resources in the IND region deteriorate, conflict over water and linked land resources is becoming prevalent. Fishers, herders, and farmers have distinct ways of utilizing water that often interplay with local tensions and competition between local communities. Seasonal water flows and coverage can contribute to disputes over cattle herding routes and use of flood plains. Terrorist groups have exploited these tensions by challenging the legitimacy of land use tariffs imposed on pastoralists who depend on the IND for dry season pastures.[18]

Chemical contamination of surface water is driven by industrial and municipal waste. Nitrates, phosphorous, cyanide, arsenic, and lead are often found to be well above recommended limits across Mali.[24] Samples collected close to gold panning sites and dyeing industries revealed localized contamination of cyanide in the Bani River.[24,25] Lead levels outside of Bamako and Segou have also been found to be eight to nine times above the World Health Organization's (WHO) guidelines for drinking water.[25,26] High concentrations of lead pose public health risks because it can bioaccumulate in fish, which is a key source of protein local diets.

Inadequate wastewater management systems exacerbate surface water pollution. Small sewerage systems and small open-air sewage canals in some urban centers like Bamako serve a small subset of the population and are mainly designed to process graywater. The eight operational wastewater treatment stations around the country provide limited treatment for select facilities, such as hospitals, airports, government buildings, and inflows from the mini sewerage systems.[27,28]

Groundwater Outlook

KEY TAKEAWAYS

- Groundwater usage is lower than surface water, but it is the primary source of water for drinking and domestic use in rural and urban areas. It is also commonly used for livestock watering.
- Poor sanitation systems contaminate groundwater in cities like Bamako.
- High groundwater salinity threatens agricultural yields where flood irrigation is widely practiced and contaminates some drinking water sources in northern Mali.

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

Groundwater is abundant and largely underexploited with total annual groundwater withdrawals accounting for less than one percent of total water use.[3] Overall, there are approximately 26,000 boreholes which are distributed among the Senegal and Niger Basins and more sparsely in the Sahelian and Saharan zones.[12] Groundwater is almost exclusively used for drinking, domestic use, and livestock watering and is abstracted through both traditional and modern wells. An estimated 87 percent of the rural population and 30 percent of the urban population depend on groundwater, although in Bamako 55 percent of the population depend on groundwater.[2,29] Groundwater is also important for watering cattle, which require an annual supply almost equal to household demand.[2] Demand for groundwater may increase in the future given the high rate of projected population growth and more frequent and severe droughts. Dense clusters of shallow wells, particularly in urban areas, may create localized depressions or lead to declining water tables, rendering shallow wells ineffective.

Inadequate sanitation systems and poorly constructed wells have contributed to pathogenic contamination in groundwater. In Bamako, poorly constructed and sealed boreholes, and lack of protection within the wellhead area are common pathways for contamination. Bamako's highly permeable soils create direct connections between pit latrines and the shallow water table.[31,32] Water quality tests indicate high concentrations of E. Coli and nitrates concentrations that are almost 3 times higher than the WHO guidelines around Bamako.[4,26] Industrial contaminants such as arsenic and chromium have also been detected in wells in Bamako and may be linked to tannery effluent and diffuse contamination from used electronics at dumping sites.[32]

Irrigation has increased salinity in groundwater and soil. Decades of flood irrigation in riparian farming areas around Bamako have raised the water table 30m to 50m since the 1940s, with the water table now situated just one meter below the surface in some locations.[33] The saturation of previously dry and naturally alkaline soils, along with the evaporation and concentration of salts in irrigation waters, is responsible for large increases in both water and soil pH and salinity, which can reduce agricultural yields. Northern Mali's fossil water also suffers from naturally high salinity, rendering it unsuitable as drinking water sources in some cases.[34] Contamination of groundwater in more rural areas and close to mining sites in the south and southwest is not well understood, although contamination from mercury and arsenic are suspected.[33]

Water Resources and Climate

KEY TAKEAWAYS

- Precipitation may increase slightly nationally but decline in northern Mali, although projections are highly uncertain and any gains in precipitation would likely be offset by higher evaporation rates.
- Interannual precipitation variability is increasing and causing more frequent and intense droughts, particularly around the IND and in the north.
- Climate change is expected to increase the frequency of heavy rainfall events in southern Mali. The IND is most at risk for damaging floods that threaten people, crops, cattle, and infrastructure.

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

Variability in inter-annual precipitation is increasing but total average precipitation has decreased, and there have been longer, more severe, and more frequent droughts.[35] Total annual precipitation is 282 mm/year although regional precipitation varies from around 150 mm/year in the north to 800-1300 mm/year in the south. Temperatures have increased by 1.2°C relative to the 1960s.[35] By 2050, temperature increases of 0.9°C–1.5°C are projected along with more variable precipitation.[35] Projections also indicate marginal increases in overall precipitation but reduced precipitation in the north.[35]

Climate change will increase the prevalence of drought, decrease water availability, and increase food insecurity. Despite projected increases in precipitation, hotter temperatures will increase evaporation and reduce surface water availability. Increased interannual variability in precipitation and more frequent drought will impact rainfed agriculture and reduce the scale of wetlands and lakes. Mali experienced two extreme droughts in the 1970s and 1980s and five major droughts between 1987 and 2007.[36] The drought between 1968 and 1973 sparked a regional famine across the Sahel. Mali lost 40 percent of its cattle and 40 percent of its crops, inducing famine that led to the death of 250,000 people.[37] The Global Hunger Index classifies Mali at "serious" risk of hunger due to imbalances in seasonal water supply and a high prevalence of rainfed agriculture.[38]

Intense rainfall events leads to extreme flooding in the IND. Seasonal flooding in the IND is part of the natural hydrological cycle and is important for local livelihoods and ecosystems. Excessive wet season flooding, however, destroys infrastructure, washes out crops, drowns livestock, and results in the loss of human life. In 2019, floods affected over 78,000 people, primarily in Timbuktu, Gao, Segou, and Koulikoro.[39] Climate change is expected to increase the frequency of heavy rainfall events in southern Mali.[23]

FIGURE 2: DROUGHT RISK

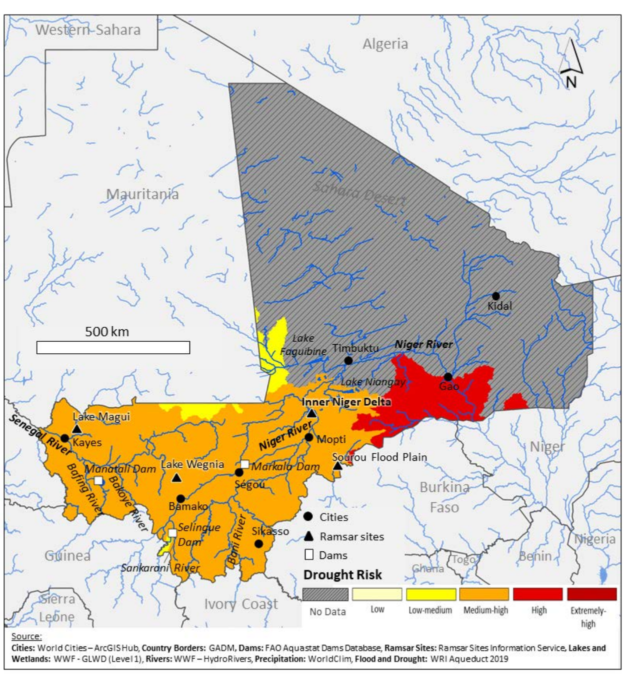
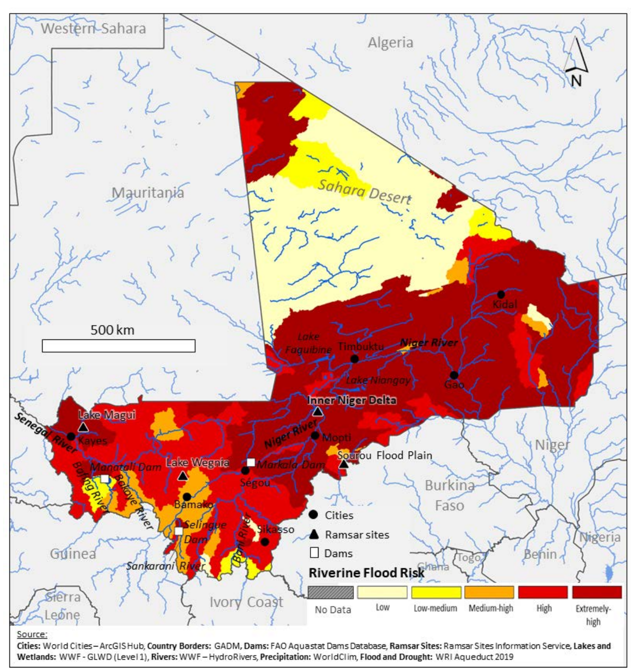


FIGURE 3. RIVERINE FLOOD RISK



Water Policy and Governance

KEY TAKEAWAYS

- Low funding, technical capacity, and coordination impede implementation of national plans for hydraulic development and ecosystem and river protection programs. Surface and groundwater quality studies and quality data are generally limited, which can impede water management.
- The lack of clear effluent discharge and water quality standards, as well as routine and comprehensive water quality monitoring mandates, affects enforcement of permits, which can be a key source of revenue for the sector.
- Stakeholder engagement in planning decisions is important for mitigating tensions between upstream and downstream water users, particularly along the Niger River and in the IND.

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.

Funding constraints and low technical capacity impede water sector planning and implementation. Only 27 percent of total staffing targets were met at the DNH in 2018 and more than half of 49 planned SLH offices are non-operational.[43] International funding sources account for 92 percent of funding secured for the DNH's 2020-2022 planning term, which only meets 62 percent of their target budget.[43,44] While the National Water Law envisions user and polluter-pay principles, these approaches have not been effectively implemented. Hydraulic infrastructure planning and operations should consider downstream ecosystems and stakeholders to minimize risks to food insecurity and competition for water. The IND's wetland management plan established under the Sustainable Development Program for the Inner Niger Delta (PPD-DIN) acknowledges upstream infrastructure but does not incorporate projected impacts on flow and their effects on livelihoods and the IND ecosystems.[22]

Mali also participates in three transboundary river basin authorities responsible for facilitating international cooperation on basin planning, development, and protection. The international agreements governing the Senegal and Niger Rivers manage flows based on reasonable use principles rather than fixed allocations. These transboundary entities serve as international platforms for planning and managing hydraulic infrastructure, hydroelectric power generation and distribution, and water quality protection and erosion control, and in the case of the Senegal River, enable multilateral ownership of hydraulic infrastructure. The Niger River Basin Agency (ABFN) exists as an independent government entity that focuses on environmental protection plans, invasive aquatic species removal, and efforts to mitigate erosion and river sedimentation to safeguard fluvial transportation.

TABLE 2. KEY LAWS, POLICIES, AND PLANS

Name	Year	Purpose
National Water Code	2002	Establishes rights and obligations of water users and state institutions, as well as their roles in basin-level planning. In 2019, the code was revised to integrate the updated national water policy and sectoral goals for the next decade though it remains provisional.
National Water Policy	2006	Defines national priorities and approaches for developing and managing water supply and adopts an IWRM-based approach to policy objectives. In 2019, proposed revisions to the water law emphasized potable water access, institutional collaboration, modernization of hydraulic infrastructure, and sectoral capacity building and financing.
National Action Plan for Integrated Water Resources Management (PANGIRE)	2009, revised in 2019	Sets specific targets and timelines for achieving policy objectives to effectively implement the national water policy. Covering the 2019-2030 timeframe, PANGIRE will establish an IWRM-institutional framework, promote sectoral technical capacity, improve sustainable IWRM finance mechanisms, and enforce sectoral regulations.

Water Quality Monitoring

Groundwater and surface water quantity and quality data is collected from 95 hydrometric stations and 160 monitoring wells and stored in a database called SIGMA.[43] The National Water Law and IWRM planning documents do not specify minimum effluent or water quality standards, and have no provisions for bulk water quality monitoring. However, the National Water Policy calls for monitoring of drinking water quality in accordance with WHO standards. The DNH conducted over 15,000 surface water quality tests in 2018, however, many of these tests were not as part of a systematic monitoring program.[43]

TABLE 3: WATER RESOURCES MANAGEMENT ENTITIES

Mandate	Institution	Roles and Responsibilities
Transboundary	Niger Basin Authority (ABN)	Commissioned in 1980, the member states include Niger, Benin, Chad, Guinea, Côte d'Ivoire, Mali, Nigeria, Cameroon, and Burkina Faso. Supports integrated basin development related to energy, water resources, agriculture, animal husbandry, fisheries, forestry, and transportation, among other functions.
	Organization for the Enhancement of the Senegal River (OMVS)	Established in 1972, the OMVS is represented by Mali, Mauritania, and Senegal. Implements the Senegal River Convention, coordinates studies and projects, and establishes policy.
	Volta River Basin Authority (ABV)	The ABV has been operational since 2009, represented by its Benin, Burkina Faso, Cote d'Ivôire, Ghana, Mali, and Togo. Conducts stakeholder engagement for basin development initiatives, authorizes construction of hydraulic infrastructure and other basin projects, harmonizes national policies, builds capacity of member states, and coordinates research initiatives.
National	Ministry of Energy and Water (MEE)	Responsible for bulk management of water resources and hydroelectric power generation.
	National Hydraulics Directorate (DNH)	Housed within the MEE, it is responsible for water policy development, basin development master plans, and serves as a national coordinating mechanism for water policy implementation. Charged with disseminating water quality information to public.
	National Water Council	Advises in policy and basin development and acts as a national forum for stakeholder engagement.
Sub-national	Regional Hydraulics Directorates (DRH)	Support the DNH in developing and implementing 20-year river basin development master plans. Leads water sector infrastructural development at local levels. Engages local stakeholders when developing policy and basin management plans.
	Local Hydraulic Services (SLH)	
	Regional Water Councils	Conflict resolution among stakeholders and advise policy and basin development planning.
	Local Water Councils	

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This profile was produced by USAID's Sustainable Water Partnership activity.

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